

AN ENGINEERING STUDY OF THE DRIFTWOOD-BENEZETTE
GAS FIELD IN PENNSYLVANIA

Clem Brandon Connally

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An Engineering Study of the

Driftwood - Benezette Gas Fields

In Elk, Cameron, and Clearfield Counties of Penna.

By Commander C. B. Connally* and P. F. Fulton**

I. Introduction

This paper presents a petroleum engineering approach to the evaluation of production practices employed in the Driftwood-Benezette gas field in Pennsylvania, and compares the results of such practices with those which might have been accomplished had the field been developed and operated in the most efficient manner, or in accordance with modern petroleum conservation laws.

The Driftwood-Benezette gas field is important to this study only in that it provides a means for illustrating production practices generally employed in all Pennsylvania gas fields. Therefore, no attempt has been made to set forth details of engineering and geologic interest not closely related to production practices.

Petroleum production practices in Pennsylvania have remained the same in principle since the discovery of the Drake well in 1859. There are no laws restricting petroleum production even though it is a well known fact that "wide-open" flow may cause great underground losses of oil or gas; moreover, there are no laws protecting landowners' correlative rights—the right to enjoy the use of one's property so long as this enjoyment does not do injury to others.¹

There have been several proposals² for petroleum conservation laws which would require or encourage the development and operation of a petroleum reservoir as a single unit rather than on the wasteful and costly basis of "every man for himself." None has been enacted, however, and it appears that Pennsylvania may become the leading oil and gas producing state where no such laws are in effect. It is indeed a mystery why no such laws have been enacted. One would think that Pennsylvania, the founding state of the petroleum industry, would have been a leader in petroleum regulatory law. There must be some merit to petroleum conservation and unitization laws, for no state has ever repealed such a law. The Interstate Oil Compact Commission, which through engineering, research, and other committees functions to advise the various states on petroleum regulatory measures, has recommended the enactment of a unitization law.³

Does it not seem logical that there should be a minimum waste of petroleum resources, and that a landowner should be permitted to recover his fair share of the oil or gas underlying his land, and only his fair share, without the drilling of unnecessary wells?

Perhaps many Pennsylvanians are not acutely aware of the waste of their petroleum resources or the infringement on their correlative rights caused by maximum-rate production practices employed in Pennsylvania. This study has been made in an attempt to illustrate, quantitatively, the effects of such practices as they relate to natural-gas production.

The Driftwood-Benezette field provides a good example for illustrating natural-gas production practices in Pennsylvania. This field was intensely drilled soon after its discovery and allowed to produce at maximum rate. Each landowner had to get his gas to the surface before his neighbor drained it away. It is the authors' opinion that this caused the drilling of about 200 more wells than would have been necessary to produce the field efficiently, and that open-flow production will cause the underground loss of at least 20 billion cubic feet of gas, with a net value of approximately \$2,000,000.

Unfortunately, accurate results cannot be obtained from the data available. Throughout this study, however, the authors continually strove to favor the use of results and assumptions which would not exaggerate the adverse effects of existing production practices.

II. Inadequacy of Engineering Data

It became apparent at the beginning of this study that the lack of petroleum regulatory laws has resulted in an inadequacy of engineering data.

It is impossible for engineers to make accurate engineering studies, upon which plans for future gas production, transportation, storage and marketing must be based, without complete and accurate engineering information. Furthermore, this information must be readily available, at a central source, to all interested parties.

In 1935 the Bureau of Mines introduced a method for computing gas-well capacities and for applying this information to production practices.⁴ The basic equation⁵ set forth in that report

is used throughout the natural gas producing industry—even in Pennsylvania—yet the data available on Pennsylvania wells for use in that equation are entirely inadequate for accurate calculations.

Though there are no laws preventing operators from obtaining these data on their own wells, few will voluntarily close in a well or restrict its production while their neighbor drains gas from under their land at a maximum rate. Further, in order to provide maximum benefit, this information must be standardized and compiled under a well organized program, enforced by a central authority and maintained readily available at a central source.

This lack of adequate information has obviously lead to inaccuracies in much of the data that have been obtained. Probably the greatest inaccuracies have been in measuring the shut-in pressures of the wells, the very heart of the information used in petroleum engineering studies.

Another source of difficulty to an engineer is the confidential nature of production information on privately owned wells. An accurate evaluation of a well's performance requires the comparison of that well with other wells in the near vicinity, and an evaluation of the reservoir as a whole may require the use of performance data on any well in the reservoir.

Specific examples of either inadequate or inaccurate information encountered during the course of this study are listed as follows:

1. Shut-in well pressures are often inaccurate. Most wells were shut in for less than 24 hours when their pressures were recorded, some for only an hour or less.

2. The entire reservoir has never been shut in and the average pressure recorded, nor are individual wells shut in periodically for this purpose. One accurate reservoir pressure, after sufficient gas had been produced to show a pressure decline, would have been sufficient to compute total gas reserves. As the situation stands, operators are merely guessing at gas reserves, and no one will ever know how much gas is lost due to production practices.

3. Production information on privately owned land is confidential and, there-

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best advantage its resources of men and materials.

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Wrather Retires As Director Of U. S. Geological Survey

Dr. William Embry Wrather, who recently retired as Director of the Geological Survey "has guided Survey Activities through 12 years of growth in service to the Nation during the difficult years of war and the later period of adjustment to an expanding economy," according to Secretary of the Interior Douglas McKay. Dr. Wrather was appointed in 1943, at a time when heavy demands were being made on the Survey for emergency services to the Nation in the midst of a world war.

Born in Kentucky and a graduate of the University of Chicago in geology and law, Dr. Wrather brought to the Survey a unique combination of administrative abilities gained through years of experience in the petroleum industry.

In 1954 he was given the 50th John Fritz Medal, and cited as "a geologist of worldwide experience and fame; an outstanding scientist and historian; a wise leader distinguished for his service to the Nation."

Under Dr. Wrather's leadership much progress was made in various facets of the science of hydrology and in the accumulation of basic water facts.

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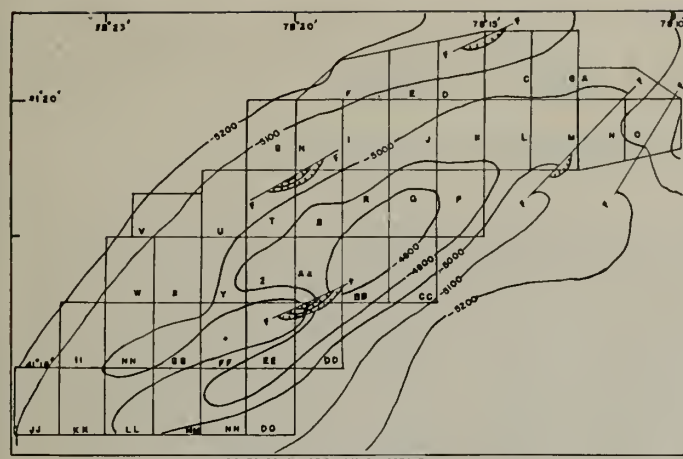


Figure 1—Structure Map, Driftwood-Benezette Gas Field

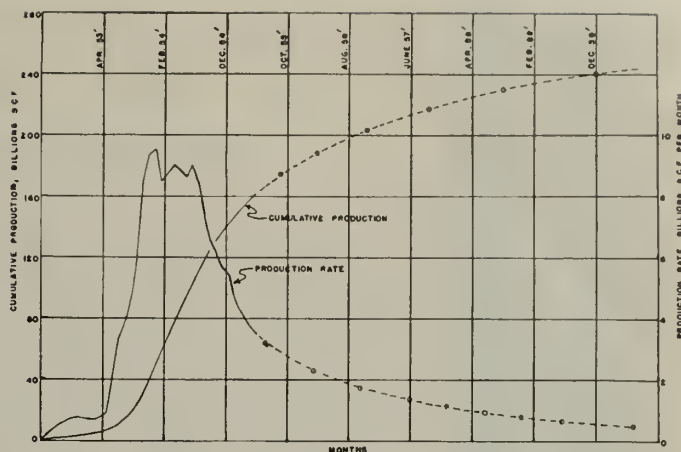


Figure 3—Cumulative Production and Production Rate vs. Time

fore, not available to the public or to all interested producing companies.

4. No records could be found showing shut-in pressures for wells on more than one occasion after having been cut in to the pipeline. This information is necessary in order to determine a well's performance characteristics and behavior as described in Section V, A and B.

5. No one producer or regulatory body has all the data on all the wells in the reservoir. Absence of monthly production rates for all wells is the most important example of this inadequacy. Other missing information might be as follows: The drilling method used, whether or not a well was shot, original well-head pressures and shut-in time, and whether or not a well had been abandoned.

6. The reservoir temperature has never been measured.

7. Very few reservoir sand thicknesses have been recorded.

8. Well locations are not recorded in a standard form.

9. Neither the porosity nor the permeability of the sand has ever been measured.

In view of the above, the results brought out in this study are not nearly so accurate nor significant as they otherwise might have been. Perhaps the inadequacy of this study will serve to indicate the necessity for such state statutes as will provide for the compilation of information necessary to conduct accurate engineering studies.

III. History of Operations

A. The Reservoir

The Driftwood-Benezette gas field is the largest known gas field in Pennsylvania, covering about 42,000 acres in Elk, Cameron, and Clearfield Counties. Production is from the highly faulted Oriskany sandstone, which in this area is mostly "medium-grained, light gray,

quartzose, slightly calcareous."¹⁰ The Oriskany is capped by the Onondaga limestone formation.

Figure 1 shows the approximate area of the reservoir superimposed on a contour map on the Oriskany sandstone as constructed by Fettke.⁷ Figure 2 shows locations of all wells numbered in the sequence in which they were completed or drilling operations abandoned, although numbers for dry holes have been omitted on the drawing.

It should not be construed that the reservoir has such a jagged boundary as is indicated by the block areas in Figures 1 and 2. These blocks established by the authors were used to compute the average reservoir pressure as described in Section IV.

This field is located on the Driftwood anticline, the highest point on which is the Driftwood dome, located about one mile northeast of the town of Driftwood. This dome is not shown in Figure 1

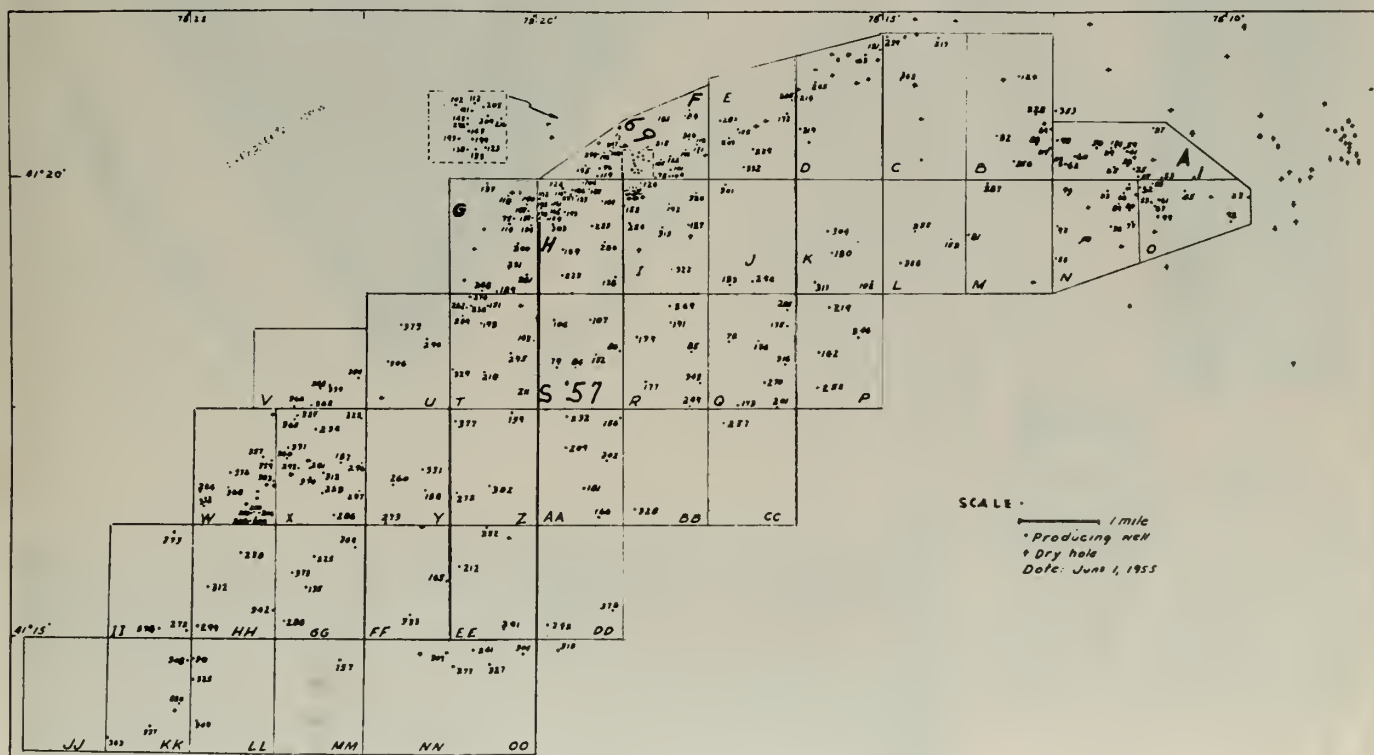


Figure 2—Block area map, Driftwood-Benezette Gas Field

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Fig. 107AA

Fig. 107

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since the dome itself proved to be outside the productive boundary of the reservoir, as indicated by the numerous dry holes shown just to the northeast of the reservoir in Figure 2.

The northeast or Driftwood end of this reservoir was discovered first. The discovery well was Sylvania's S. C. Eaton No. 1 (Figure 2, well 1-A) completed September 15, 1951. Since this well was situated relatively low on the southwest plunge of the Driftwood dome, subsequent tests were made high on the dome in and around the town of Driftwood, none of which proved productive apparently because of a tight sand stratigraphic closure at the northeast end of the reservoir. Development was then shifted down the plunge to the southwest.

The Keta Oil and Gas Company's Charleroi Mountain Club No. 1 (Figure 2, well 57-S) on the Benezette dome opened the Benezette end of the reservoir in December, 1952. Then in March, 1953, the Benezette Valley Development Company brought in the William Woodring No. 1 (Figure 2, well 69-F). This well was extremely important in that it is some 300 feet lower on the flanks of the Benezette dome than the Charleroi well, indicating that the Driftwood-Benezette field was much larger than had previously been estimated.⁸ This led to the furious drilling race between private landowners which resulted in the dense well pattern as shown in Figure 2, areas F, G and H. Presumably, if the areas to the south had not been mostly state-owned land, the entire field would have been drilled into a similar pattern.

B. Drilling and Production Practices

1. Drilling and Gauging

Drilling operations reached a peak in August, 1953, when 22 producing wells were brought in. The rate then dropped slightly and leveled off at about fifteen to twenty wells per month until July, 1954, at which time there began a rapid decline in the drilling rate.

Most of the early drilling was with cable tools which averaged about sixty feet per day. Rotary drilling was later used, which averaged about 180 feet per day; however, lost circulation and completion problems were frequently caused by the high density (17 pounds per gallon) drilling mud. Completion problems were often overcome by drilling-in with cable tools, but a more recent practice of using air-rotary drilling with gas completions has been highly successful in eliminating both of these difficulties. The air-rotary has shown a penetration rate of about twice that of the regular rotary.⁹

All methods employ the practice of setting a seven-inch O. D. casing about ten feet into the Onondaga limestone, and then drilling a 6½-inch hole into or through the Oriskany sandstone.

Open-flow capacities of wells are measured with pitot tubes while the gas is discharged to the atmosphere. Shut-in pressures are generally recorded after

wells have been closed in for 24 hours, although the rush to cut the wells into the pipeline frequently permits only a few hours shut-in time.

2. Production Practices

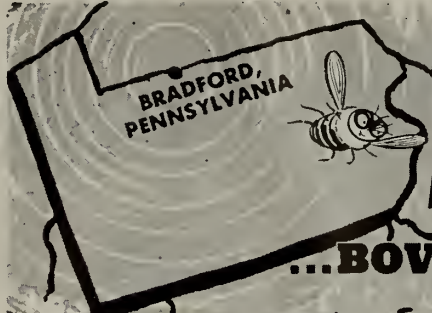
Little can be said of production practices except that wells are cut in to the pipeline as quickly as possible and permitted to flow at maximum rate. Figure 3 shows the cumulative production and production rate of the field plotted against time. The dotted portion of the curves represents the predicted recovery and recovery rates as explained in detail in Section V, C.

There has been no evidence of water drive during production from this field.

There have been occasions of wells being drowned out by water, but this difficulty has frequently been relieved, at least temporarily or partially, by shutting in the wells for a few days.

IV. Determination of Reserves

An accurate determination of gas reserves in a reservoir can be made only when accurate reservoir pressures are known. Since the Driftwood-Benezette reservoir has never been shut in in order to determine a reservoir pressure, and since pressures for individual wells are not periodically recorded, any method used in computing reserves is largely guesswork. The original pressure was most probably about 4,020 pounds per



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square inch gage, as measured at the well head. Obviously, no other pressure would be needed to compute reserves if the boundaries of the reservoir, the porosity, the per cent water saturation, and the sand thickness were known. However, in view of the highly faulted structure of this reservoir, the probable wide variation in porosity, and the doubtful boundaries as estimated, the only practicable method for determining reserves is by the use of declining reservoir pressures with cumulative production, as is shown graphically by Figure 4, and as explained in detail later in this section.

The only course for determining the average reservoir pressure lay in averaging pressures by areas, area pressures being obtainable from original pressures for new wells. It is believed that the boundaries of the reservoir are sufficiently well established so that it can be divided into areas as shown in Figure 2, and that each area has roughly the same average porosity and sand thickness. Though this may not be entirely true, the method of averaging area pressures in order to determine the over-all reservoir pressure is not overly demanding of an accurate reservoir area, and it is not necessary that the sand thickness or porosity be known, provided each area is assumed to have equal pore space. The reservoir area as shown is comprised of forty-one approximately equal-sized blocks of about one thousand acres each.

The only difficulty lay in determining the average area pressures at a selected date or dates. The pressure recorded for a well drilled in the area on or near the selected date could not be used with any degree of accuracy, for often the well would be in such close proximity to another that its pressure would be greatly affected, or the pressure shown for a well drilled at a later date in the same vicinity might have been considerably higher. Many additional factors had to be considered, such as the location of the wells in the area, their distance apart, the length of shut-in time compared to flow rate, and pressures in adjoining areas.

It soon became apparent that many

recorded well pressures were lower than they should have been. Most of the wells were shut in for less than twenty-four hours when their pressures were recorded. This is far short of the time estimated to have been necessary for the pressure to stabilize in sand of such low permeability. It has been illustrated that pressures recorded after three days may still be well below the stabilized pressures.¹⁰

It was impossible to select any single date near which, during the early and late stages of development, wells were drilled in a majority of the areas. This

required such an extensive use of estimated area pressures that little reliability could be placed in the computed average. It was, therefore, decided to determine the one most accurate average reservoir pressure which occurred well along in the productive life of the reservoir. Only one pressure, other than the original, is needed to compute reserves, and one good pressure is considered to be more accurate than a decline curve average of several poor ones. In order to determine the most accurate pressure each block area was considered separately. Again, weighing all significant

FIGURE 6. AVERAGE WELL FLOW RATE DECLINE

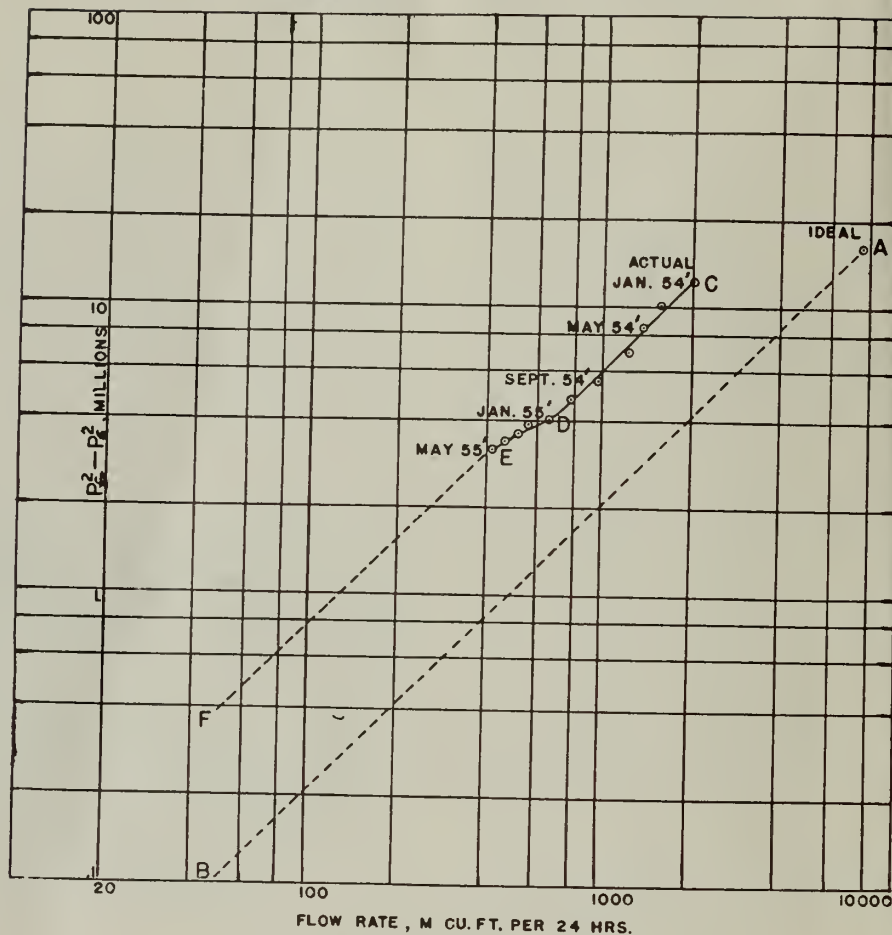


Figure 6—Average Well Flow Rate Decline

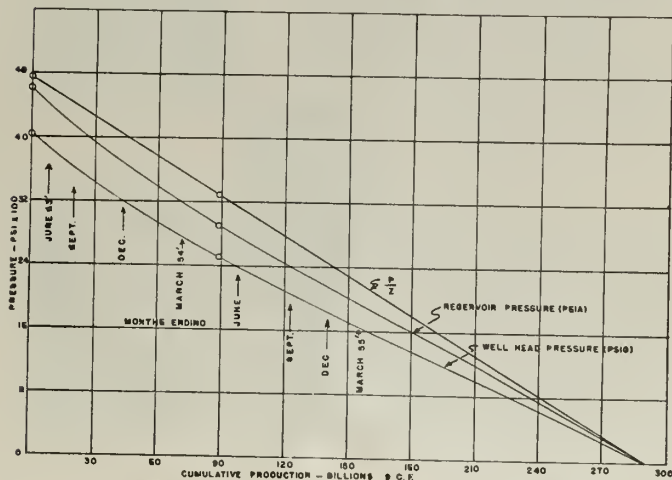


Figure 4—Pressure Decline with Cumulative Production

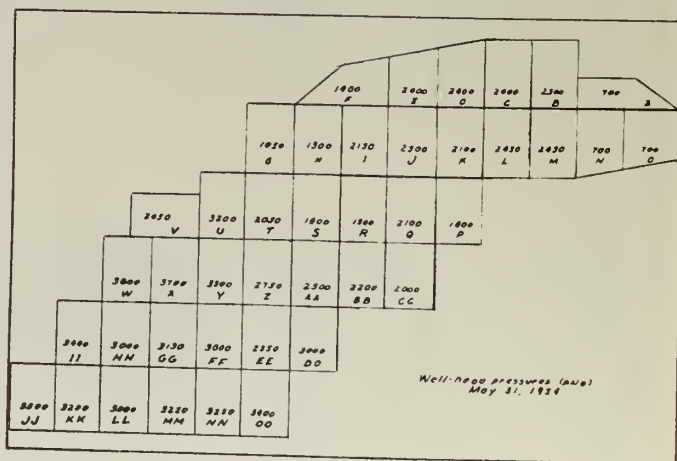


Figure 5—Pressures by Block Areas

factors stated above, every instance in which a well pressure or several well pressures appeared to reasonably represent that for the block area was recorded under the date shown. When such pressures for all areas had been recorded, the widest coverage of area pressures fell near the date of May 31, 1954. That date was, therefore, selected for determining the over-all average reservoir pressure. In cases where a block area failed to show a pressure on or near that date, it was possible to interpolate between dates on either side of May, 1954, or to estimate the area pressure from those shown for surrounding areas. Well-head pressures thus determined are shown in Figure 5. The average of these gage pressures came to 2,490 pounds per square inch.

The pressure due to the weight of the column of gas was computed using the equation

$$P_w = \frac{P_z R T 144}{M H} - .5 P_x^*$$

where

- P_w = well-head pressure in pounds per square inch absolute.
- P_x = pressure due to the weight of the gas column in pounds per square inch,
- Z = gas compressibility factor at average temperature in the well bore and at well-head pressure,
- R = gas constant,
- T = average temperature of the gas column,
- M = molecular weight of the gas,
- H = average depth of the reservoir below the surface.

If natural gas expanded upon release in pressure exactly in accordance with Boyle's law, the pressure decline curve would merely be a straight line through the original reservoir pressure and the May 31, 1954 reservoir pressure plotted against cumulative production as of May 31, 1954. However, since natural gas does not conform exactly to Boyle's law, the compressibility factor had to be considered. Calhoun shows that reservoir pressure (P) divided by the compressibility factor for the gas (Z) at reservoir conditions will plot as a straight line against cumulative production.¹¹ Compressibility factors were, therefore, computed for the two above reservoir pressures and a straight line plot made between the two P/Z points thus determined. The accuracy of the curve was checked analytically and original gas calculated to be 289 billion standard cubic feet. The reservoir pressures as they would be measured both in the reservoir and at the surface (Figure 4) were computed from the P/Z curves, using compressibility factors and values for the pressure due to the weight of the gas column as are shown graphically in Figures 7 and 8.

The 289 billion standard cubic feet of gas, as calculated to have been originally in the reservoir, at first appeared high, considering the present low production rate from the wells. An additional cal-

culation was, therefore, made to determine the porosity of the sand, using 42,000 acres which has been estimated as the area of the reservoir, and an average sand thickness of 17 feet as estimated from the few well records showing this information. The porosity thus calculated came to 4.18 per cent. This porosity certainly does not appear to be excessive, considering the nine per cent and 8.34 per cent porosities found, respectively, for Oriskany sand samples blown from wells in the Tioga¹² and the Leidy gas fields.¹³

In consideration of the above, the 289 billion cubic feet does not appear to be excessive. An additional similar calculation of reserves was made, however,

using the absolute minimum feasible pressures for block areas as of May 31, 1954. This calculation showed 255 billion standard cubic feet as the original gas content of the reservoir. The original calculation is considered to be the more accurate.

V. Operations

A. Determination of Average Well Productive Capacity

The equation $Q = C(P_r^2 - P_w^2)$ as described in the Bureau of Mines Monograph 7 is also applicable to groups of wells.²⁰ The average well productive capacity coefficient, C , may therefore be obtained by averaging the C 's computed for each well by dividing Q by $(P_r^2 - P_w^2)^{.5}$. Values for Q and for P_w are known as



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*Derived, using gas law equations, slightly inaccurate as the Z is based on the well-head pressure instead of the average pressure in the well.

each well is completed and an open flow test is made. Since the value of n was not known, it was necessary to average the production rates (Q) for wells producing under the same ($P_r^2 - P_s^2$). Further, since little confidence could be placed in the accuracy of the lower pressures, it was decided to use wells showing well-head pressures near 3,500 pounds per square inch. Thirty such wells showed an average Q of 7,300M cubic feet per day. The pressure due to the weight of the column of gas in these wells averaged about 500 pounds per square inch, bringing the P_r value to 4,000 pounds per square inch. Since P_s can be neglected for these large-hole high-pressure wells flowing against atmospheric pressure, 7,300 (Q) can be plotted against 16,000,000 ($P_r^2 - P_s^2$) on

logarithmic paper as is shown by point A in Figure 6. This gives one point on the logarithmic plot, but does not of course show the slope of the line which can be used to determine values of Q at different values of ($P_r^2 - P_s^2$). It was decided to use an n value of one (viscous flow) in order to simplify calculations and to preclude the exaggeration of the adverse effects of production practices as is brought out in Section V, B and C. Using this n value of one, the coefficient (C) for the 30 wells came to .456. These values of C and n were justified by an average value of C equal to .45 for 127 wells on which the recorded data appeared to be the most accurate. The value of C for each individual well in this case was obtained by dividing the flow rate (Q) by ($P_r^2 - P_s^2$), P_r being the

closed-in individual well-head pressure plus the pressure caused by the weight of the gas column, and P_s again neglected.

Readers might be interested in the calculation of average permeability where the value of C equal to .456 was substituted in the Darcy's law radial flow equation for viscous flow. Though a rough assumption had to be made for the drainage radius and though the flow may not be considered as radial in all cases, the computed permeability of 4.05 millidarcies as compared to the estimated permeability of ten millidarcies tends to substantiate the assumption that the value of C is not excessive. Two samples blown from wells in the Leidy gas field averaged 10.9 millidarcies.²¹

In consideration of the above, the curve AB in Figure 6 may be considered to represent the production rate that could have been expected from the average well with decreasing values of ($P_r^2 - P_s^2$) had the physical characteristics of the well and the producing formation remained constant, and had the wells been so spaced as to have the average formation pressure acting on each well.

B. Effect of Well Spacing and Production Practices on Production Rate

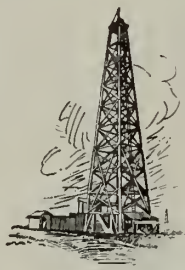
As pointed out in the previous section, curve AB (Figure 6) represents the declining production rates with declining ($P_r^2 - P_s^2$) values that could have been expected from average, undamaged, properly spaced wells. Curve CD (Figure 6) represents the actual average production rate per well with declining average reservoir pressures as shown in Figure 4. Points on curve CD were determined by dividing the total monthly production rates by the average number of producing wells as of the date indicated and plotting these rates per well against the ($P_r^2 - P_s^2$), P_r being considered as the formation pressure shown by Figure 4 and P_s being dependent upon the line pressure and is estimated as 600 pounds per square inch. The deficiency in production rate per well for any value of ($P_r^2 - P_s^2$) is represented by the horizontal distance between the two curves. This loss can be attributed to local pressure depletions in densely drilled areas and to physical damage to wells brought on by the rapid production rate.

Production losses caused by water coning, well caving, etc., cannot be well illustrated from the data available, although it would be a simple procedure to shut in wells occasionally and to plot the Q versus the ($P_r^2 - P_s^2$) on logarithmic paper. A line through successive points thus obtained would indicate whether or not a well is being damaged. A curve that bent toward the pressure axis would be indicative of water coning or other factors hindering deliverability. If only two points are available, and a line through the two points has a slope greater than one (more than 45 degrees to the pressure axis), it will, in the authors' opinion, be indication of well damage. This procedure was attempted for the few state wells on which records

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could be found showing shut-in pressures sometime after their original gaging. However, curves thus obtained only served to prove the inadequacy and inaccuracy of recorded data. One curve showed a reverse slope, indicating lower flow rate with increasing formation pressure.

The Bureau of Mines back-pressure method for analyzing the deliverability of gas wells is a much more thorough and detailed procedure than that described above. Far greater benefits than that discussed above may also be derived from their method, although it requires the restricting of a well's flow for considerably more time than production practices in Pennsylvania permit.

C. Estimated Losses in Ultimate Recovery

Although it is impossible to predict the ultimate gas recovery from this reservoir with any degree of accuracy, it is fairly obvious in view of the declining production rate that an uneconomical production rate will be reached long before 289 billion cubic feet of gas have been produced.

Curve DE, Figure 6, shows a recent increasing rate of decline in production rate. This may be due to a variety of factors, such as

1. Water fingering cutting off relatively high pressure gas zones.
2. Water coning near the well bore, reducing the effective sand thickness.
3. Water condensation, reducing the effective permeability to the gas.
4. Water accumulation in the well bore.
5. Well caving.
6. Structural conditions within the reservoir.
7. The temporary shutting in of an increasing number of wells (since the rate is based on the number of producing wells as drilled rather than the actual number in operation).
8. Almost total pressure depletion in densely drilled areas.

It is the authors' opinion, however, that conditions in the reservoir may soon stabilize and that the flow rate after that time will continue in a directly proportional relationship with $(P_r^2 - P_s^2)$; at least this is the best that can be expected. This is illustrated by the curve EF, Figure 6. Though there is little chance that this curve will hold true to the abandonment date, it is not unreasonable to expect that it will hold approximately true for the next few years. This curve may be used in conjunction with the reservoir pressure curve (Figure 4) to provide a trial and error means for predicting future production and production rates. The dotted portions of the curves (Figure 3) were derived in this manner, considering a gradually decreasing value of P_s to zero in the year 1959. By the end of the year 1959 there should have been about 240 billion cubic feet of gas produced from this reservoir.

In consideration of curves AB and EF (Figure 6) and assuming a minimum economic flow rate (Q) of 50MCF per day at zero back pressure (P_s), the reservoir could be expected to be abandoned at an average pressure (P_r) of 632 pounds per square inch, whereas in the "ideal" case the abandonment pressure would be 316 pounds per square inch. This, according to Figure 4, reflects a loss of about 22 billion cubic feet of gas due to inefficient production practices.

Actually, it is anyone's guess as to just how far into the future this reservoir will produce gas at an economic rate. Most likely there will be numerous wells capable of producing gas at an economic rate for many years to come.

It is highly probable, however, that water fingering and coning has or will cut off relatively high pressure zones within the reservoir, and that a reduced effective permeability to gas caused by water coning and condensation will seriously curtail production and reduce the ultimate recovery. An estimated loss of approximately 20 billion cubic feet of gas is considered to be conservative.

VI. Evaluation of Results

A. Operational Aspects

Although this study has developed no absolute proof that there will be substantial losses in ultimate recovery of gas from this reservoir, it does indicate that such losses are very likely and pre-

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sents definite proof that a great amount of manpower and materials have been unnecessarily expended. Curves AB and CD (Figure 6) show that actual production per well was only about 35 per cent of what might have been expected from the properly-spaced average well. or that about one-third of the wells, if properly spaced and undamaged, should have given the same production rate. As was pointed out in Section V, A, this figure is based on a conservative estimate of the slope of the logarithmic curve AB (Figure 6) equal to one. It is possible that this curve could have had a slope of less than one, showing an increasingly wide separation between the "ideal" and "actual" curves with decreasing pressures, and therefore an increasingly poorer comparison of the actual well production rate with that of the ideal.

The ideal number of wells can only be determined by an economic balance of a great many factors, such as recoverable gas in place, drilling costs, back pressure required to prevent damaging the well or the producing formation, market demands and commitments and others. The back pressure required can be determined accurately by the Bureau of Mines method, but even this is subject to economic considerations. It may, for example, be more economical to permit minor damage to the well than to hold the back pressure sufficiently high to prevent damage entirely. Some states force the application of back

pressure by restricting gas production to 25 per cent of open flow capacity. However, this restriction is also intended to prevent gas production in excess of market demands, and there is no reason known to the authors why Pennsylvania should restrict production to this rate if it can be shown that significant damage will not occur to wells producing at higher capacities. All of the above factors can best be weighed and applied through a unit operation plan, assisted perhaps by a well-spacing regulation.

It is probable that no more than two billion cubic feet per month would have been the ideal production rate from the Driftwood-Benezette field. Gas companies taking gas from this field must contract for vast quantities of gas from the Southwest to meet commitments during the winter months. Furthermore, the nature of pipeline operations as well as economic factors in the producing Southwest demand the establishment of long-term contracts with little or no seasonal variations in gas deliveries. This requires the delivery of large quantities of gas to this area during the summer months which must be stored in underground reservoirs. It is therefore obvious that the most economical rate to extract gas from this field would be a long-term rate necessary to augment deliveries from the Southwest with a minimum of storing required.

According to curve AB (Figure 6), two billion cubic feet per month could have been produced early in the productive

life of the field ($P_i = 4,600$) with 27 wells producing at 25 per cent of open-flow capacity, and with 100 wells at this capacity five years later when the 120 billion cubic feet produced would have caused the reservoir pressure to drop to about 2,400 pounds per square inch (Figure 4). At 50 per cent open-flow capacity, only half of these wells would be required, and 100 wells would produce two billion cubic feet or more per month until 175 billion cubic feet of gas had been produced. Assuming that the flow rate could reach a maximum at the lower pressures without causing significant damage to the wells or the formation, 100 wells would sustain the 2 billion cubic feet per month rate for almost nine years or until 210 billion cubic feet of gas had been produced. Does not this appear more efficient and logical than has been the actual practice of drilling around 300 producing wells to obtain the flow rate shown in Figure 3?

The above comparison of actual practices with those which might have been employed under unit operations or under well spacing regulations does not show a comparison of ultimate recovery losses. It was illustrated in Section V, C that there should be at least 20 billion cubic feet of gas lost because of inefficient production practices. Though structural conditions in the reservoir might not permit such high ultimate recovery in either the actual or the ideal case, it is probable that unit operations or ade-

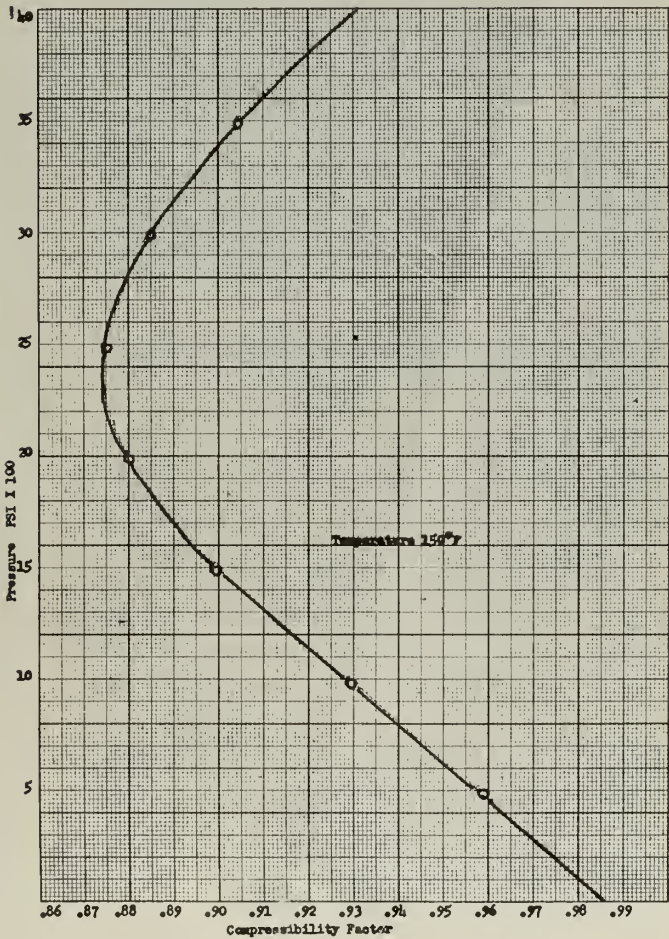


Figure 7—Compressibility factor vs. Pressure

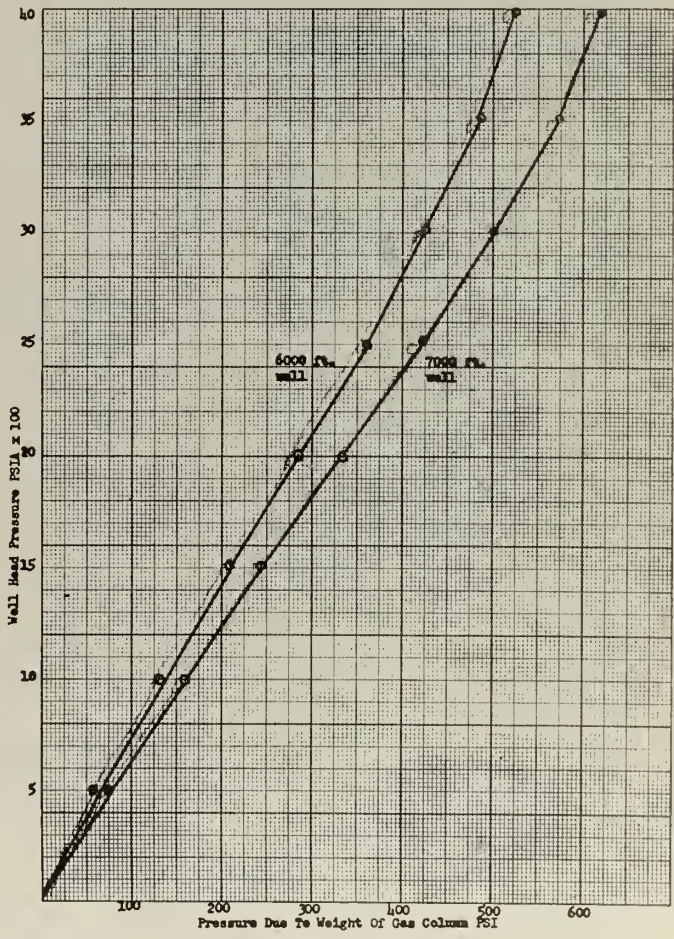


Figure 8—Pressure due to weight of gas column of well-head pressure

quate well spacing regulations would provide for more efficient exploration and thereby for a production rate closely approaching that shown by the curve AB (Figure 6).

B. Economic Aspects

1. General

The economic aspects of production practices may be illustrated roughly as follows:

(a) Before this reservoir is abandoned there will probably have been 300 producing wells drilled—200 more than is conservatively estimated to be the ideal as stated in the previous section. At \$75,000 per well, this will amount to an unnecessary expenditure of \$15,000,000.

(b) It is estimated that at least 60 billion cubic feet of gas will have been stored and re-extracted beyond that which would have been necessary at the two billion per month rate. At an estimated cost of five cents per thousand cubic feet for storing and re-extracting, this will amount to \$3,000,000.

(c) Twenty billion cubic feet of gas estimated to be lost due to open flow production practices, at an estimated net value of about ten cents per M cubic feet²² will amount to a loss of \$2,000,000.

(d) It is estimated that about 75 billion cubic feet of gas would have increased in value by at least two cents per M cubic feet had it been possible to produce this gas on a seasonal contract or at a slower rate. This will amount to \$1,500,000.

(e) There have been numerous relatively minor excessive expenditures, such as expenses for operating compressor stations, additional well maintenance costs due to open flow production practices, excess gathering lines, etc.

In view of the foregoing illustration, it is reasonable to assume that \$20,000,000 have or will be wasted by the production practices employed in the Driftwood-Benezette gas reservoir. Furthermore, a large portion of these losses will be paid by the consumer in the form of high gas prices or in taxes to make up for the losses from state-owned tracts.

2. Private Landowners

Much of the land overlying this reservoir is privately owned small tracts of one acre or less. Such a landowner's fair share of the gas, considering 40,000 acres total and 280 billion cubic feet of gas as recoverable, is 7,000 M cubic feet. At one-eighth royalty this figure is further reduced to roughly 900 M cubic feet, which would amount to \$247.50 at the current price of 27½ cents per M cubic feet. It is conservatively estimated that many small tract landowners have or will receive at least a hundred times this figure. Their excess profits obviously resulted in losses from less densely drilled areas, which in this field are mostly state-owned tracts.

Conclusion

It is concluded that there have been about 200 excess wells drilled in the

Driftwood-Benezette field; that there could not possibly have been a fair and equitable distribution of the gas among the various landowners; that very probably there have or will be large quantities of gas left in the reservoir because of open-flow production practices; that sound engineering principles are not observed in gaging wells and in evaluating their performance, and that all of these are directly attributable to the lack of petroleum regulatory statutes in Pennsylvania. It is further concluded that the general public supports a large share of the inequities, gas losses and excess expenses either in higher gas prices or in decreased revenue from publicly owned land.

The obvious recommendation, therefore, is that the citizens of Pennsylvania demand the enactment of state statutes which will prevent this waste of manpower, materials, and petroleum resources, and which will insure the protection of correlative rights of landowners.

The details of the varied petroleum conservation measures and unitization statutes are beyond the scope of this paper. The average citizen, however, should not be so much concerned with these details as by the fact that nothing is being done to remedy the current inefficient and unfair production practices. Citizens should place their faith in an Oil and Gas Committee appointed for the purpose of recommending appropriate conservation and unitization statutes

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It is additionally recommended that the state immediately institute a program to acquire, compile and correlate information needed for accurate engineering studies, and to make this information readily available to all interested parties. No information relating to well production should be confidential. The very least that should be done is the enactment of a law requiring that

all gas wells be shut in for a minimum of 48 hours once a year and that shut-in pressures be recorded and reported to an appropriate state regulatory body. Open-flow capacities, or flow rates against stated back pressures, should be recorded at the time wells are shut in, and likewise reported. Though this information will not suffice for accurate computation of the wells' performance by the Bureau of Mines back-pressure method, it will provide for considerably more accurate engineering studies than are currently possible. This recommendation would be superfluous if adequate petroleum conservation laws were en-

acted, for effective conservation presupposes a requirement for accurate knowledge of both the gas reservoir and the producing wells, which can only be gained from extensive and accurate data.

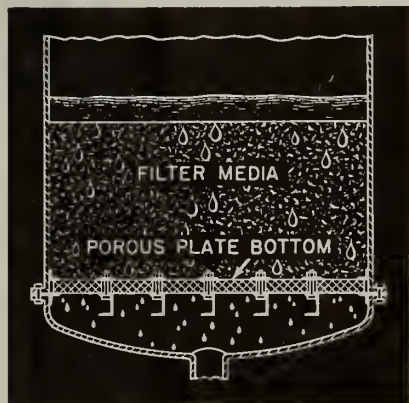
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ENGINEERING STUDY OF THE DRIFTWOOD-BENEZETTE

GAS FIELD IN PENNSYLVANIA

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FOREWORD

This paper presents a petroleum engineering approach to the evaluation of production practices employed in the Driftwood-Benezette gas field in Pennsylvania, and compares the results of such practices with those which might have been accomplished had the field been developed and operated in the most efficient manner, or in accordance with modern petroleum conservation laws.

The Driftwood-Benezette gas field is important to this study only in that it provides a means for illustrating production practices generally employed in all Pennsylvania gas fields. Therefore, no attempt has been made to set forth details of engineering and geologic interest not closely related to production practices.

Grateful acknowledgment is made to the engineers and geologists of the Manufacturers Light and Heat Company and the New York State Natural Gas Company for their cordial reception of the author in his quest for information and for their time and effort expended in making information available; to Professor H. G. Hotset, Head of the Petroleum Engineering Department, University of Pittsburgh, and Professor P. F. Fulton, Associate Professor, Petroleum Engineering Department, University of Pittsburgh, for the suggestion of the study and for their helpful comments and recommendations; and to the U. S. Naval Postgraduate School, Monterey, California, for their sponsorship of the petroleum logistics curriculum at the University of Pittsburgh through which the author was provided with the basic opportunity for preparing this paper.

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I. INTRODUCTION

Petroleum production practices in Pennsylvania have remained the same in principle since the discovery of the Drake well in 1859. There are no laws restricting petroleum production even though it is a well known fact that "wide-open" flow may cause great underground losses of oil or gas; moreover, there are no laws protecting landowners' correlative rights -- the right to enjoy the use of one's property so long as this enjoyment does not do injury to others.¹

There have been several proposals² for petroleum conservation laws which would require or encourage the development and operation of a petroleum reservoir as a single unit rather than on the wasteful and costly basis of "every man for himself." None has been enacted, however, and it appears that Pennsylvania may become the leading oil and gas producing state where no such laws are in effect. It is indeed a mystery why no such laws have been enacted. One would think that Pennsylvania, the founding state of the petroleum industry, would have been a leader in petroleum regulatory law. There must be some merit to petroleum conservation and unitization laws, for no state has ever repealed such a law. The Interstate Oil Compact Commission, which through engineering, research, and other committees functions to advise the various states on petroleum regulatory measures, has recommended the enactment of a unitization law.³ Does it not seem logical that there should be a minimum waste of petroleum resources, and that a landowner should be permitted to recover his fair share of the oil or gas underlying his land, and only his fair share, without the drilling of unnecessary wells?

¹References are listed in the Bibliography.

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Perhaps many Pennsylvanians are not acutely aware of the waste of their petroleum resources or the infringement on their correlative rights caused by maximum-rate production practices employed in Pennsylvania. This study has been made in an attempt to illustrate, quantitatively, the effects of such practices as they relate to natural-gas production.

The Driftwood-Benezette field provides a good example for illustrating natural-gas production practices in Pennsylvania. This field was intensely drilled soon after its discovery and allowed to produce at maximum rate. Each landowner had to get his gas to the surface before his neighbor drained it away. It is the author's opinion that this caused the drilling of about 200 more wells than would have been necessary to produce the field efficiently, and that open-flow production will cause the underground loss of at least 20 billion cubic feet of gas, with a net value of approximately \$2,000,000.

Unfortunately, accurate results cannot be obtained from the data available. Throughout this study, however, the author continually strove to favor the use of results and assumptions which would not exaggerate the adverse effects of existing production practices.

The loss of underground gas which has occurred and is occurring in the Driftwood-Benezette field has been estimated. Assuming the average permeability of the gas-bearing strata in the field, the loss of gas is estimated to be at least 20 billion cubic feet. The loss of gas is estimated to be at least 20 billion cubic feet. The loss of gas is estimated to be at least 20 billion cubic feet.

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II. INADEQUACY OF ENGINEERING DATA

It became apparent at the beginning of this study that the lack of petroleum regulatory laws has resulted in an inadequacy of engineering data.

It is impossible for engineers to make accurate engineering studies, upon which plans for future gas production, transportation, storage and marketing must be based, without complete and accurate engineering information. Furthermore, this information must be readily available, at a central source, to all interested parties.

In 1935 the Bureau of Mines introduced a method for computing gas-well capacities and for applying this information to production practices.⁴ The basic equation⁵ set forth in that report is used throughout the natural gas producing industry—even in Pennsylvania—yet the data available on Pennsylvania wells for use in that equation are entirely inadequate for accurate calculations.

Though there are no laws preventing operators from obtaining these data on their own wells, few will voluntarily close in a well or restrict its production while their neighbor drains gas from under their land at a maximum rate. Further, in order to provide maximum benefit, this information must be standardized and compiled under a well organized program, enforced by a central authority and maintained readily available at a central source.

This lack of adequate information has obviously lead to inaccuracies in much of the data that have been obtained. Probably the greatest inaccuracies have been in measuring the shut-in pressures of the wells, the very heart of the information used in petroleum engineering studies.

that we are going to be paid for all the work we do.

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The fact of extensive international law enforcement is important in view of the fact that the United States is a member of the United Nations and the Organization of American States, and the fact that the United States is a member of the United Nations and the Organization of American States.

Another source of difficulty to an engineer is the confidential nature of production information on privately owned wells. An accurate evaluation of a well's performance requires the comparison of that well with other wells in the near vicinity, and an evaluation of the reservoir as a whole may require the use of performance data on any well in the reservoir.

Specific examples of either inadequate or inaccurate information encountered during the course of this study are listed as follows:

1. Shut-in well pressures are often inaccurate. Most wells were shut in for less than 24 hours when their pressures were recorded, some for only an hour or less.

2. The entire reservoir has never been shut in and the average pressure recorded, nor are individual wells shut in periodically for this purpose. One accurate reservoir pressure, after sufficient gas had been produced to show a pressure decline, would have been sufficient to compute total gas reserves. As the situation stands, operators are merely guessing at gas reserves, and no one will ever know how much gas is lost due to production practices.

3. Production information on privately owned land is confidential and, therefore, not available to the public or to all interested producing companies.

4. No records could be found showing shut-in pressures for wells on more than one occasion after having been cut in to the pipeline. This information is necessary in order to determine a well's performance characteristics and behavior as described in Section V, A and B.

5. No one producer or regulatory body has all the data on all the wells in the reservoir. Absence of monthly production rates for all wells

Another source of difficulty in the construction of a well is the nature of the rock formation in which the well is to be drilled. In some cases the rock is so hard that it is necessary to use a special type of drill bit. In other cases the rock is so soft that it is necessary to use a special type of casing. In still other cases the rock is so irregular that it is necessary to use a special type of drilling method.

The following are some of the most common difficulties encountered in the construction of a well:

1. The rock is too hard to drill.
2. The rock is too soft to drill.
3. The rock is too irregular to drill.

1. The rock is too hard to drill. This is the most common difficulty encountered in the construction of a well. It is caused by the presence of hard minerals in the rock. These minerals are usually found in the form of small, hard grains. These grains are very difficult to drill through. In some cases, the grains are so hard that they will not even be drilled through by a standard drill bit. In other cases, the grains are so hard that they will only be drilled through by a special type of drill bit.

2. The rock is too soft to drill. This is also a common difficulty encountered in the construction of a well. It is caused by the presence of soft minerals in the rock. These minerals are usually found in the form of small, soft grains. These grains are very easy to drill through. In some cases, the grains are so soft that they will be drilled through by a standard drill bit. In other cases, the grains are so soft that they will only be drilled through by a special type of drill bit.

3. The rock is too irregular to drill. This is a less common difficulty encountered in the construction of a well. It is caused by the presence of irregular minerals in the rock. These minerals are usually found in the form of small, irregular grains. These grains are very difficult to drill through. In some cases, the grains are so irregular that they will not even be drilled through by a standard drill bit. In other cases, the grains are so irregular that they will only be drilled through by a special type of drill bit.

It is important to note that these difficulties are not always present in the same way. In some cases, the rock is too hard to drill in some places but too soft to drill in other places. In other cases, the rock is too irregular to drill in some places but not in other places. Therefore, it is important to carefully examine the rock formation before attempting to drill a well.

is the most important example of this inadequacy. Other missing information might be as follows: The drilling method used, whether or not a well was shot, original well-head pressures and shut-in time, and whether or not a well had been abandoned.

6. The reservoir temperature has never been measured.
7. Very few reservoir sand thicknesses have been recorded.
8. Well locations are not recorded in a standard form.
9. Neither the porosity nor the permeability of the sand have ever been measured.

In view of the above, the results brought out in this study are not nearly so accurate nor significant as they otherwise might have been. Perhaps the inadequacy of this study will serve to indicate the necessity for such state statutes as will provide for the compilation of information necessary to conduct accurate engineering studies.

providing with the data in Appendix I,

It should not be forgotten that the reservoir has such a large capacity as is indicated by the data given in Figures 1 and 2. These data established by the author were used to compute the average reservoir pressure as described in Section IV.

This field is located on the Yellowstone coastline, the highest point on which is the Yellowstone Agency located about one mile northwest of the town of Yellowstone. This area is not shown in Figure 1 since the field itself proves to be outside the productive boundary of the reservoir, as indicated by the numerous dry holes shown just to the northwest of the reservoir in Figure 2.

The reservoir is bounded east of this reservoir by the Yellowstone River. The reservoir will not extend to the south for a distance of

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about 6 billion people living on the earth.

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III. HISTORY OF OPERATIONS

A. The Reservoir

The Driftwood-Benezette gas field is the largest known gas field in Pennsylvania, covering about 42,000 acres in Elk, Cameron, and Clearfield counties. Production is from the highly faulted Oriskany sandstone, which in this area is mostly "medium-grained, light gray, quartzose, slightly calcareous."⁶ The Oriskany is capped by the Onondaga limestone formation.

Figure 1 shows the approximate area of the reservoir superimposed on a contour map on the Oriskany sandstone as constructed by Fettke.⁷ Figure 2 shows locations of all wells numbered in the sequence in which they were completed or drilling operations abandoned, although numbers for dry holes have been omitted on the drawing. Pertinent information on each producing well is shown in Appendix I.

It should not be construed that the reservoir has such a jagged boundary as is indicated by the block areas in Figures 1 and 2. These blocks established by the author were used to compute the average reservoir pressure as described in Section IV.

This field is located on the Driftwood anticline, the highest point on which is the Driftwood dome, located about one mile northeast of the town of Driftwood. This dome is not shown in Figure 1 since the dome itself proved to be outside the productive boundary of the reservoir, as indicated by the numerous dry holes shown just to the northeast of the reservoir in Figure 2.

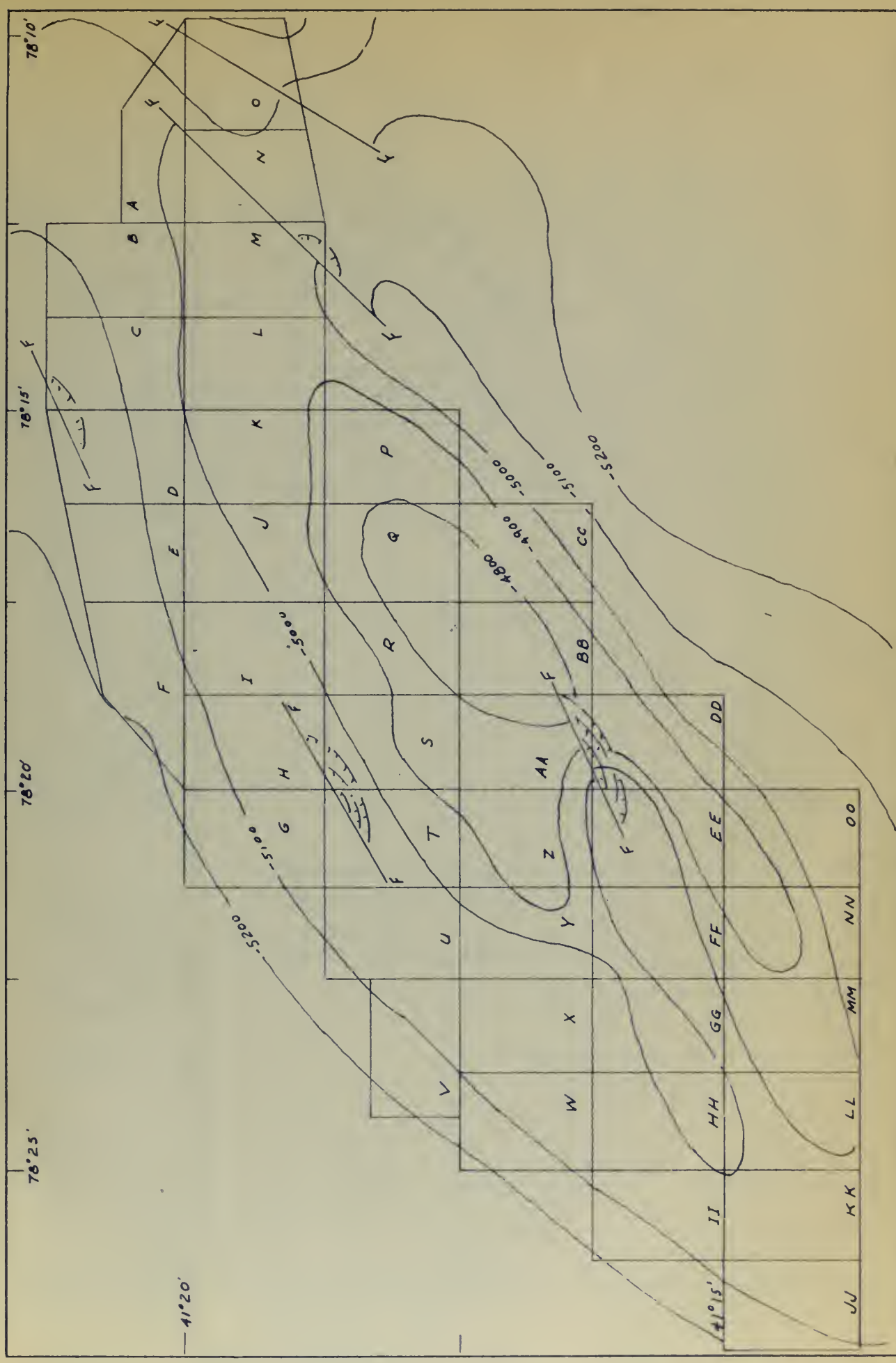
The northeast or Driftwood end of this reservoir was discovered first. The discovery well was Sylvania's S. C. Eaton No. 1 (Figure 2,

well 1-A) completed September 15, 1951. Since this well was situated relatively low on the southwest plunge of the Driftwood dome, subsequent tests were made high on the dome in and around the town of Driftwood, none of which proved productive apparently because of a tight sand stratigraphic closure at the northeast end of the reservoir. Development was then shifted down the plunge to the southwest.

The Keta Oil and Gas Company's Charleroi Mountain Club No. 1 (Figure 2, well 57-S) on the Benzette dome opened the Benzette end of the reservoir in December, 1952. Then in March, 1953, the Benzette Valley Development Company brought in the William Woodring No. 1. (Figure 2, well 69-F) This well was extremely important in that it is some 300 feet lower on the flanks of the Benzette dome than the Charleroi well, indicating that the Driftwood-Benzette field was much larger than had previously been estimated.³ This led to the furious drilling race between private landowners which resulted in the dense well pattern as shown in Figure 2, areas F, G and H. Presumably, if the areas to the south had not been mostly state-owned land, the entire field would have been drilled into a similar pattern.

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THE STATE OF NEW YORK, County of Albany, ss. I, the undersigned, Clerk of the Court of Sessions of the County of Albany, do hereby certify that the within and foregoing is a true and correct copy of the original thereof, as the same appears from the records of the Court of Sessions of the County of Albany, in and to which said original is filed for record.



Contours on Oriskany Sandstone
Figure 1 Structure Map Driftwood-Benezette Gas Field

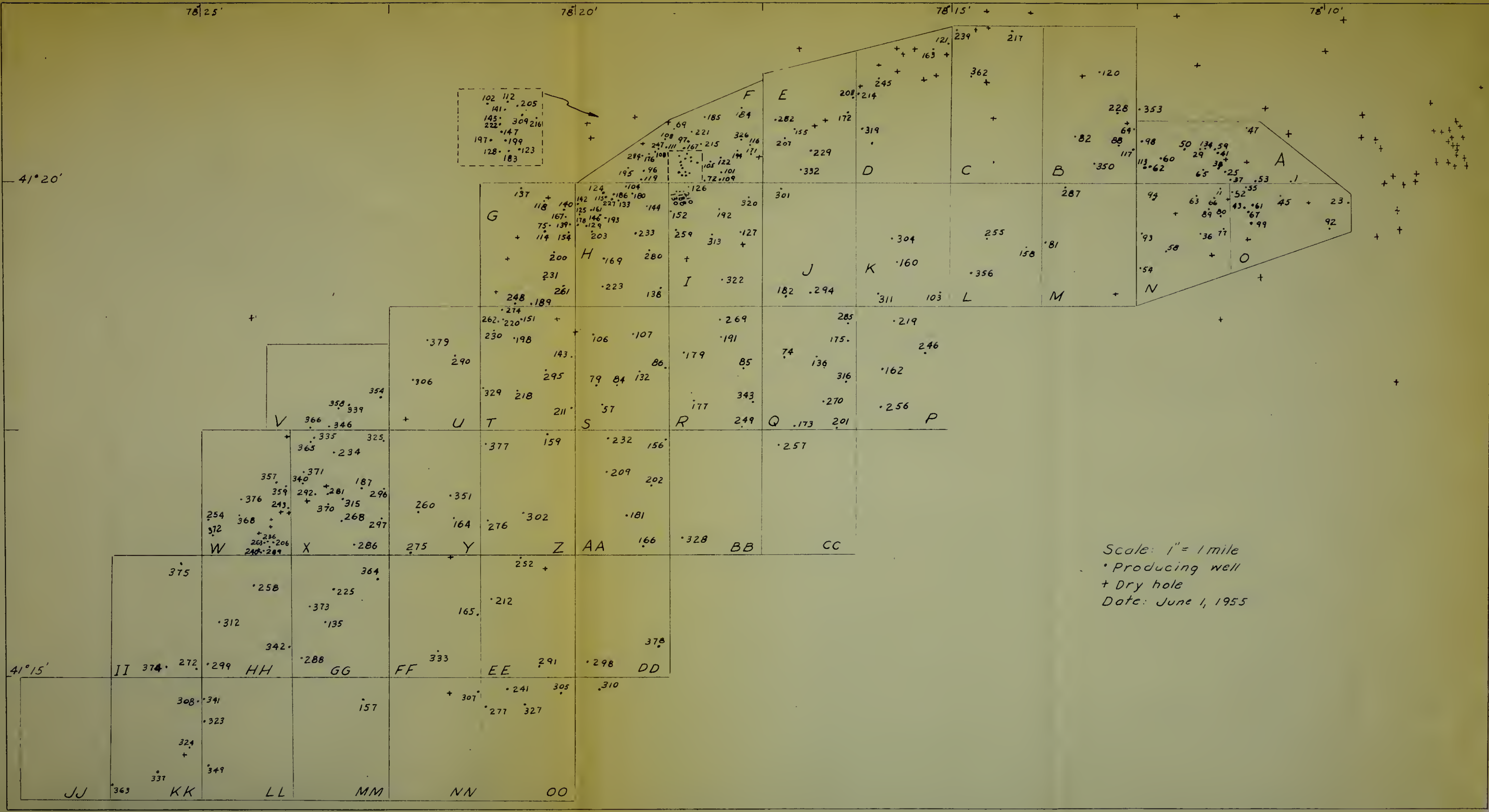


Figure 2. Block Area Map, Driftwood-Benezette Gas Field

B. Drilling and Production Practices

1. Drilling and Logging

Drilling operations reached a peak in August, 1953 when 22 producing wells were brought in. The rate then dropped slightly and leveled off at about fifteen to twenty wells per month until July, 1954, at which time there began a rapid decline in the drilling rate. Appendix IV shows a detailed breakdown of the wells by months.

Most of the early drilling was with cable tools which averaged about sixty feet per day. Rotary drilling was later used, which averaged about 180 feet per day; however, lost circulation and completion problems were frequently caused by the high density (17 pounds per gallon) drilling mud. Completion problems were often overcome by drilling-in with cable tools, but a more recent practice of using air-rotary drilling with gas completions has been highly successful in eliminating both of these difficulties. The air-rotary has shown a penetration rate of about twice that of the regular rotary.⁹

All methods employ the practice of setting a seven-inch O. D. casing about ten feet into the Onondaga limestone, and then drilling a 6 1/8 inch hole into or through the Oriskany sandstone.

Open-flow capacities of wells are measured with pitot tubes while the gas is discharged to the atmosphere. Shut-in pressures are generally recorded after wells have been closed in for 24 hours, although the rush to cut the wells into the pipeline frequently permits only a few hours shut-in time.

2. Production Practices

Little can be said of production practices except that wells are cut in to the pipeline as quickly as possible and permitted to flow at

B. Polling and Production Statistics

1. Polling and Production

Polling was conducted in 1955 in 1955, 1956 and 1957. The results were as follows: In 1955, the total number of wells was 100, of which 10 were producing. In 1956, the total number of wells was 100, of which 10 were producing. In 1957, the total number of wells was 100, of which 10 were producing.

The results of the polling are as follows: In 1955, the total number of wells was 100, of which 10 were producing. In 1956, the total number of wells was 100, of which 10 were producing. In 1957, the total number of wells was 100, of which 10 were producing. The results of the polling are as follows: In 1955, the total number of wells was 100, of which 10 were producing. In 1956, the total number of wells was 100, of which 10 were producing. In 1957, the total number of wells was 100, of which 10 were producing.

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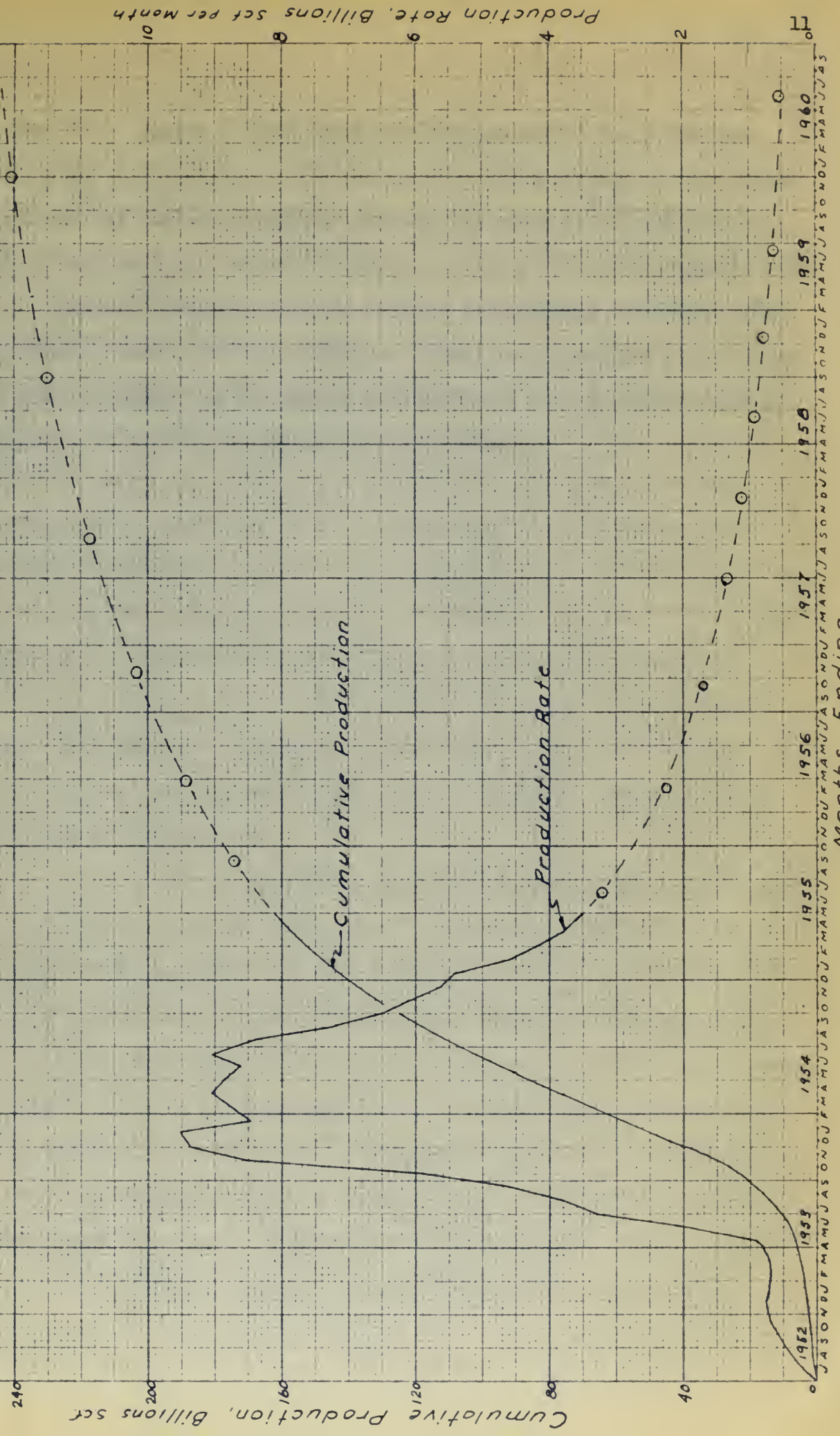
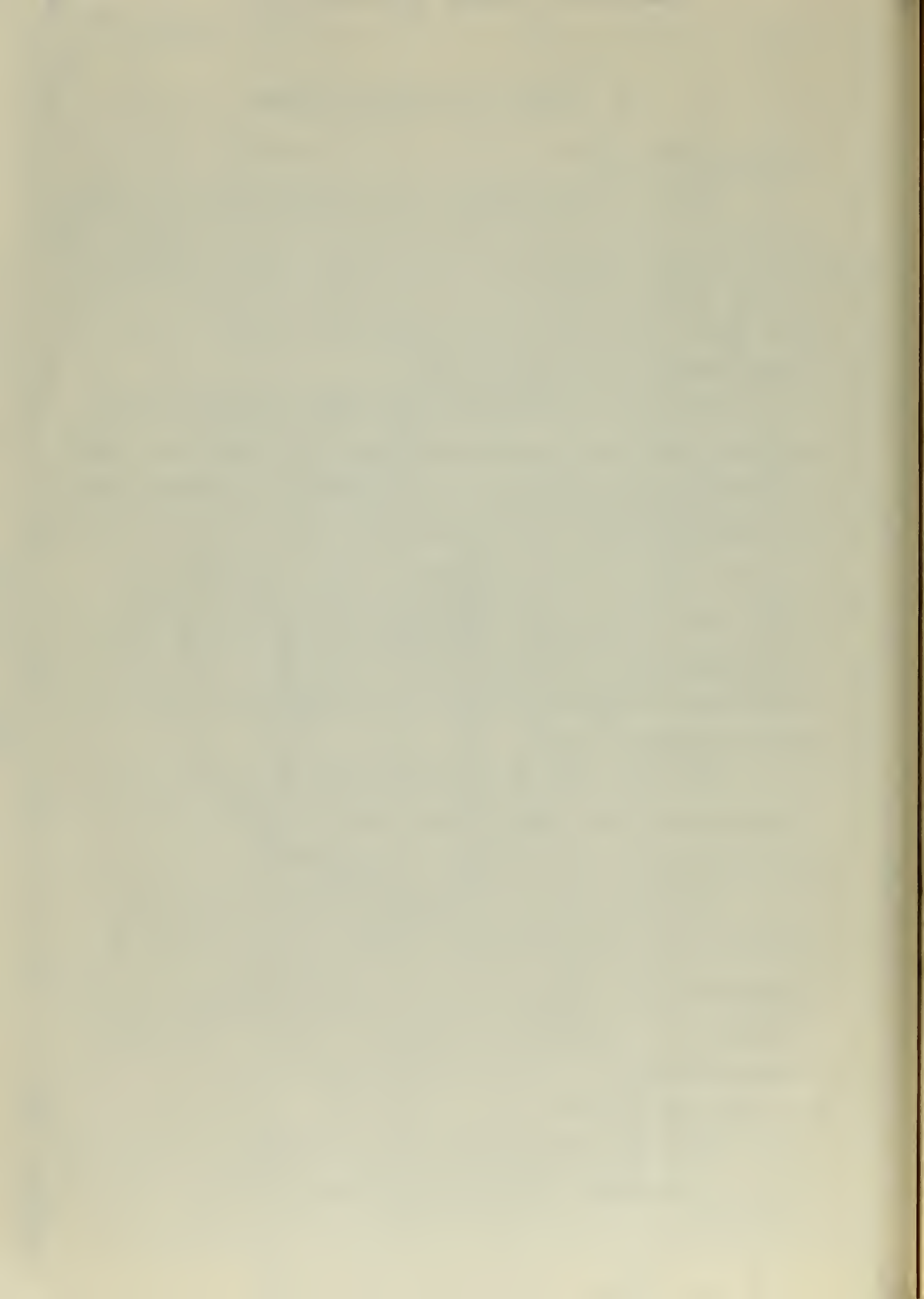


Figure 3. Cumulative Production & Production Rate vs. Time



maximum rate. Figure 3 shows the cumulative production and production rate of the field plotted against time. The dotted portion of the curves represents the predicted recovery and recovery rates as explained in detail in Section V, C. Actual production figures are shown in Appendix III.

There has been no evidence of water drive during production from this field. There have been occasions of wells being drowned out by water, but this difficulty has frequently been relieved, at least temporarily or partially, by shutting in the wells for a few days.

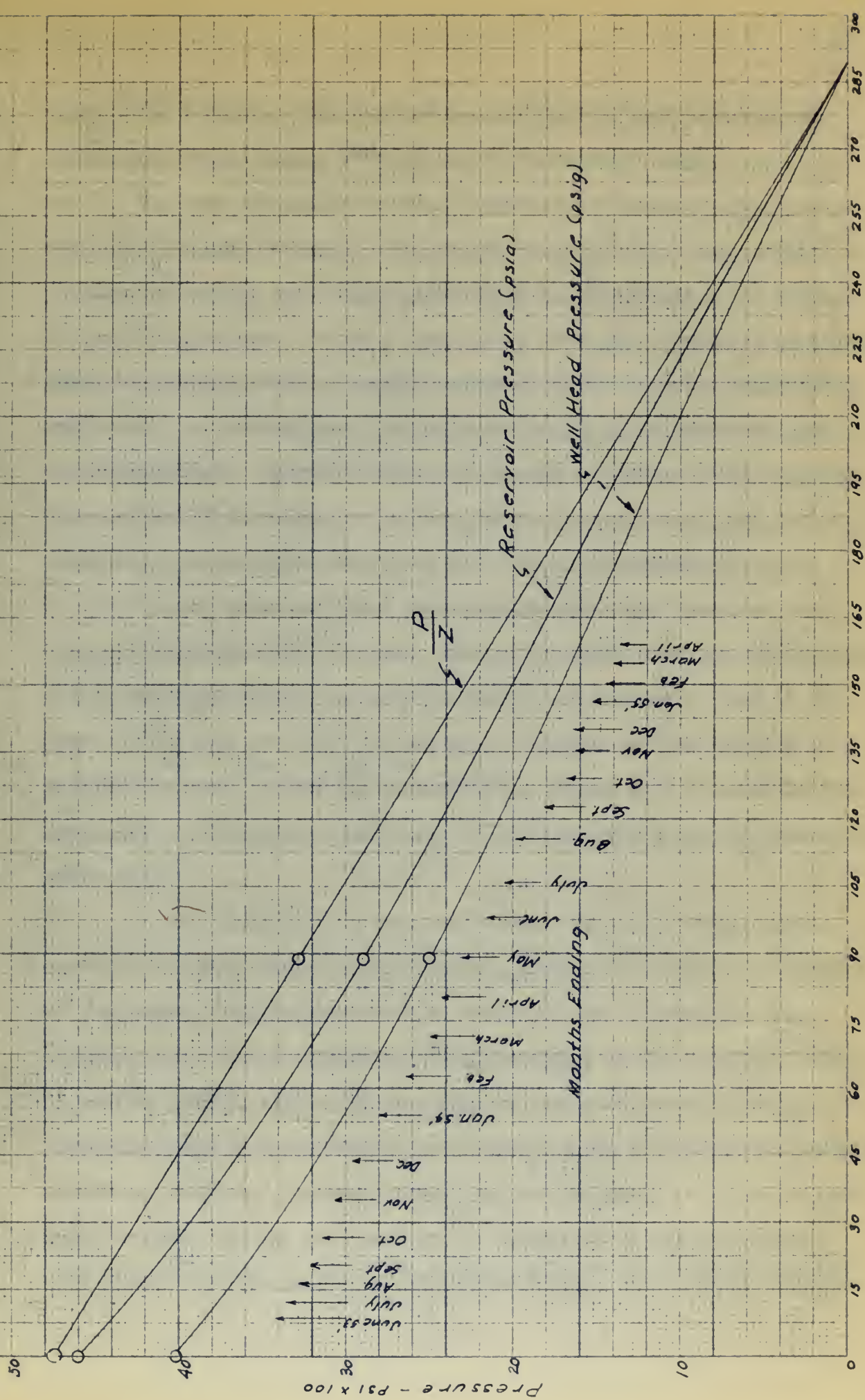
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17. DETERMINATION OF RESERVES

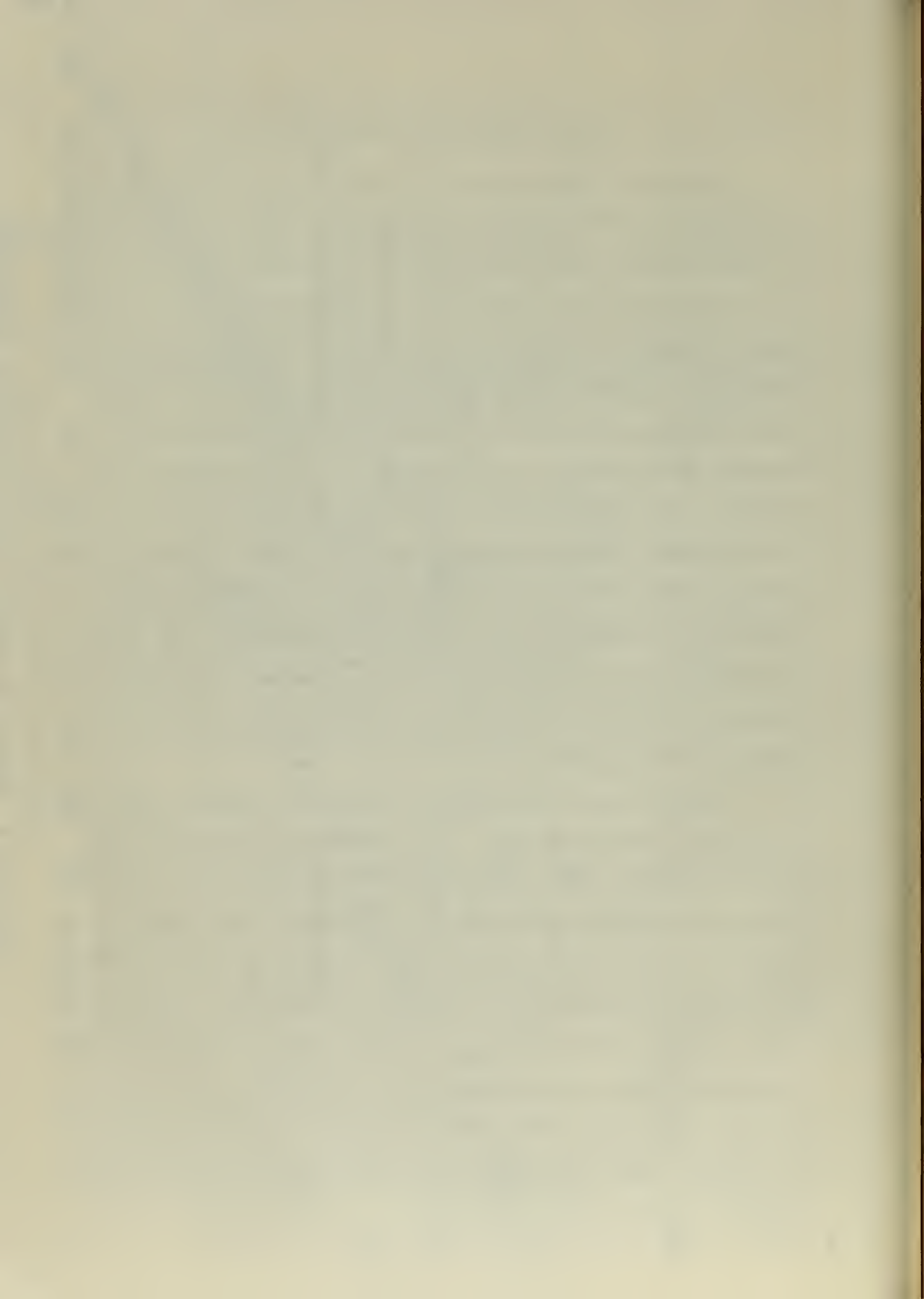
An accurate determination of gas reserves in a reservoir can be made only when accurate reservoir pressures are known. Since the Driftwood-Benezette reservoir has never been shut in, in order to determine a reservoir pressure, and since pressures for individual wells are not periodically recorded, any method used in computing reserves is largely guesswork. The original reservoir pressure was most probably about 4020 pounds per square inch gage, as measured at the well head. Obviously, no other pressure would be needed to compute reserves if the boundaries of the reservoir, the porosity, the per cent water saturation, and the sand thickness were known. However, in view of the highly faulted structure of this reservoir, the probable wide variation in porosity, and the doubtful boundaries as estimated, the only practicable method for determining reserves is by the use of declining reservoir pressures with cumulative production, as is shown graphically by Figure 4, and as explained in detail later in this section.

The only course for determining the average reservoir pressure lay in averaging pressures by areas, area pressures being obtainable from original pressures for new wells as shown in Appendix I. It is believed that the boundaries of the reservoir are sufficiently well established so that it can be divided into areas as shown in Figure 2, and that each area has roughly the same average porosity and sand thickness. Though this may not be entirely true, the method of averaging area pressures in order to determine the over-all reservoir pressure is not overly demanding of an accurate reservoir area, and it is not necessary that the sand thickness or porosity be known, provided each area is assumed to have equal pore



Cumulative Production - Billions scf

Figure 4. Pressure Decline with Cumulative Production



space. The reservoir area as shown is comprised of forty-one approximately equal-sized blocks of about one thousand acres each.

The only difficulty lay in determining the average area pressures at a selected date or dates. The pressure recorded for a well drilled in the area on or near the selected date could not be used with any degree of accuracy, for often the well would be in such close proximity to another that its pressure would be greatly affected, or the pressure shown for a well drilled at a later date in the same vicinity might have been considerably higher. Many additional factors had to be considered, such as the location of the wells in the area, their distance apart, the length of shut-in time compared to flow rate, and pressures in adjoining areas.

It soon became apparent that many recorded well pressures were lower than they should have been. Most of the wells were shut in for less than twenty-four hours when their pressures were recorded. This is far short of the time estimated to have been necessary for the pressure to stabilize in sand of such low permeability. It has been illustrated that pressures recorded after three days may still be well below the stabilized pressures.¹⁰

It was impossible to select any single date near which, during the early and late stages of development, wells were drilled in a majority of the areas. This required such an extensive use of estimated area pressures that little reliability could be placed in the computed average. It was, therefore, decided to determine the one most accurate average reservoir pressure which occurred well along in the productive life of the reservoir. Only one pressure, other than the original, is needed to compute reserves, and one good pressure is considered to be more accurate than a decline curve average of several poor ones. In order to determine

...the economy will be based on the production of goods and services.

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The only difference is in methodology: the interview and questionnaire

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Source: The staff level of the Atlanta-Fulton County Stadium and the Atlanta-Fulton County Stadium.

of research, but also will be able to contribute to society.

© 1995 American Psychological Association 0893-3200/95/\$04.00 DOI: 10.1037/0893-3200.10.4.535

—and used until 1964, when it was replaced by a more modern design.

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The location of the hills is well known, but it is not known whether the hills are

*All the above are subject to change without notice.

Bitte bestätigen Sie schnellstmöglich das Jährliche Kennzeichen 2011.

Very truly yours,

THESE RESULTS WERE REPRODUCED IN A RECENT STUDY BY

Start of the first segment is used to estimate the first segment.

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It is important to note that the results of this study are based on a cross-sectional design, which limits the ability to establish causality. Future research should employ longitudinal designs to investigate the temporal relationships between the variables studied.

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Bitte bestellen Sie zu uns ausschließlich im Jahr 2009! Gerne soll es

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Special Agent in Charge

Approved: _____ Date: _____

There is still controversy as to what the benefits of using a computer are.

• users of Internet will, therefore, not have access to any information

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then a British agent named Mr. [redacted] was sent to [redacted] to [redacted]

the most accurate pressure each block area was considered separately. Again, weighing all significant factors stated above, every instance in which a well pressure or several well pressures appeared to reasonably represent that for the block area was recorded under the date shown. When such pressures for all areas had been recorded, the widest coverage of area pressures fell near the date of May 31, 1954. That date was, therefore, selected for determining the over-all average reservoir pressure. In cases where a block area failed to show a pressure on or near that date, it was possible to interpolate between dates on either side of May, 1954 or to estimate the area pressure from those shown for surrounding areas. Well-head pressures thus determined are shown in Figure 5. The average of these gage pressures came to 2490 pounds per square inch.

The pressure due to the weight of the column of gas was computed as shown in Appendix II, using the equation

$$P_w = \frac{P_x ZRT Mh}{144} - .5P_x^*$$

where P_w = well head pressure in pounds per square inch absolute,

P_x = pressure due to the weight of the gas column in pounds per square inch,

Z = gas compressibility factor at average temperature in the well bore and at well head pressure,

R = gas constant,

T = average temperature of the gas column,

M = molecular weight of the gas,

h = average depth of the reservoir below the surface.

*Derived, using gas law equations, slightly inaccurate as the Z is based on the well head pressure instead of the average pressure in the well.

The most common mistake made by students is to assume that the function $f(x)$ is continuous at $x = a$ simply because $f(a)$ is defined. This is not true. For example, consider the function $f(x) = \begin{cases} x^2 \sin(1/x) & x \neq 0 \\ 0 & x = 0 \end{cases}$. This function is defined at $x = 0$, but it is not continuous at $x = 0$ because the limit $\lim_{x \rightarrow 0} f(x)$ does not exist. The function oscillates infinitely as x approaches 0, and therefore does not approach a single value. This is a classic example of a function that is defined at a point but not continuous at that point.

The function $f(x) = \begin{cases} x^2 \sin(1/x) & x \neq 0 \\ 0 & x = 0 \end{cases}$ is a classic example of a function that is defined at a point but not continuous at that point. The function oscillates infinitely as x approaches 0, and therefore does not approach a single value. This is a classic example of a function that is defined at a point but not continuous at that point.

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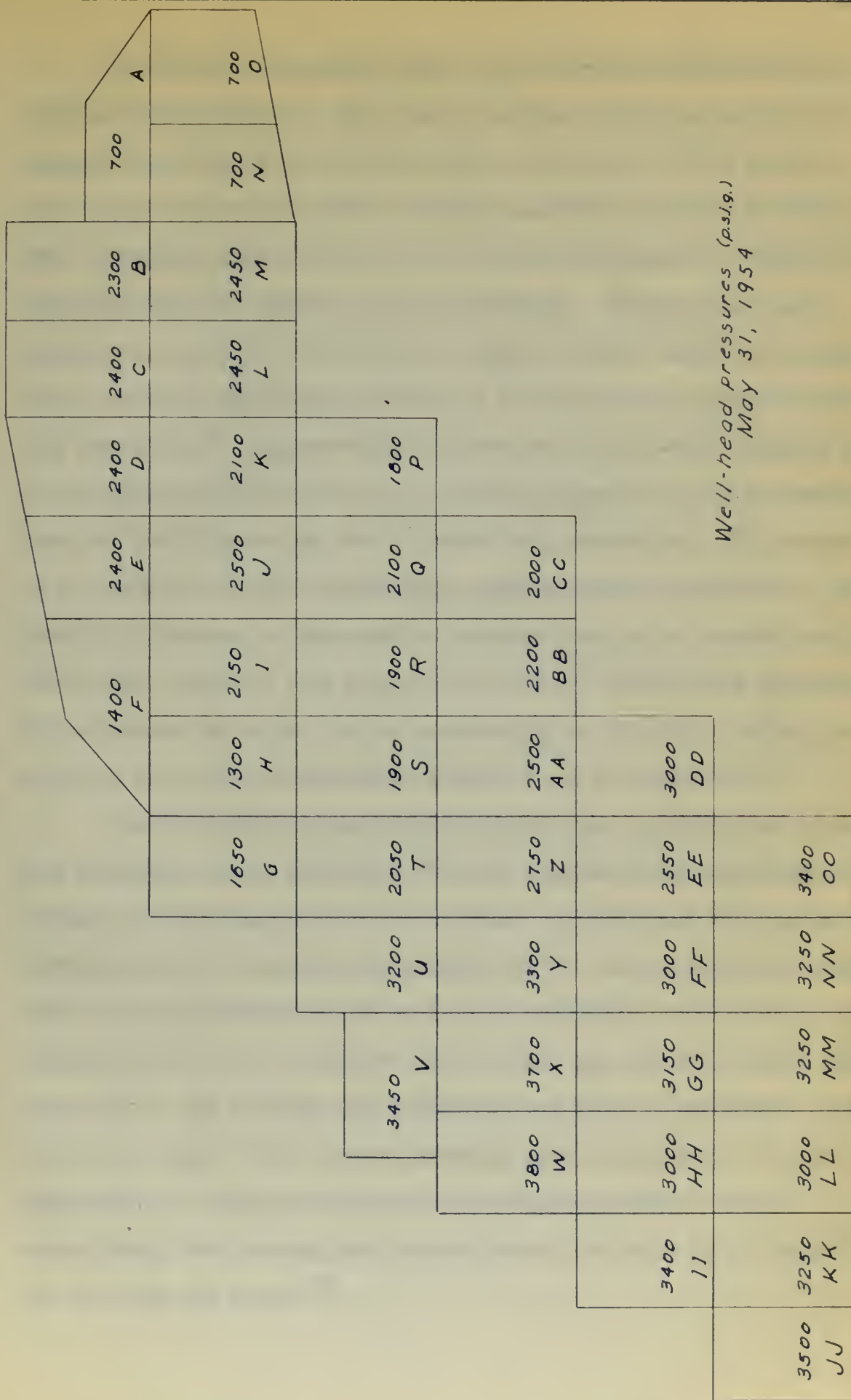
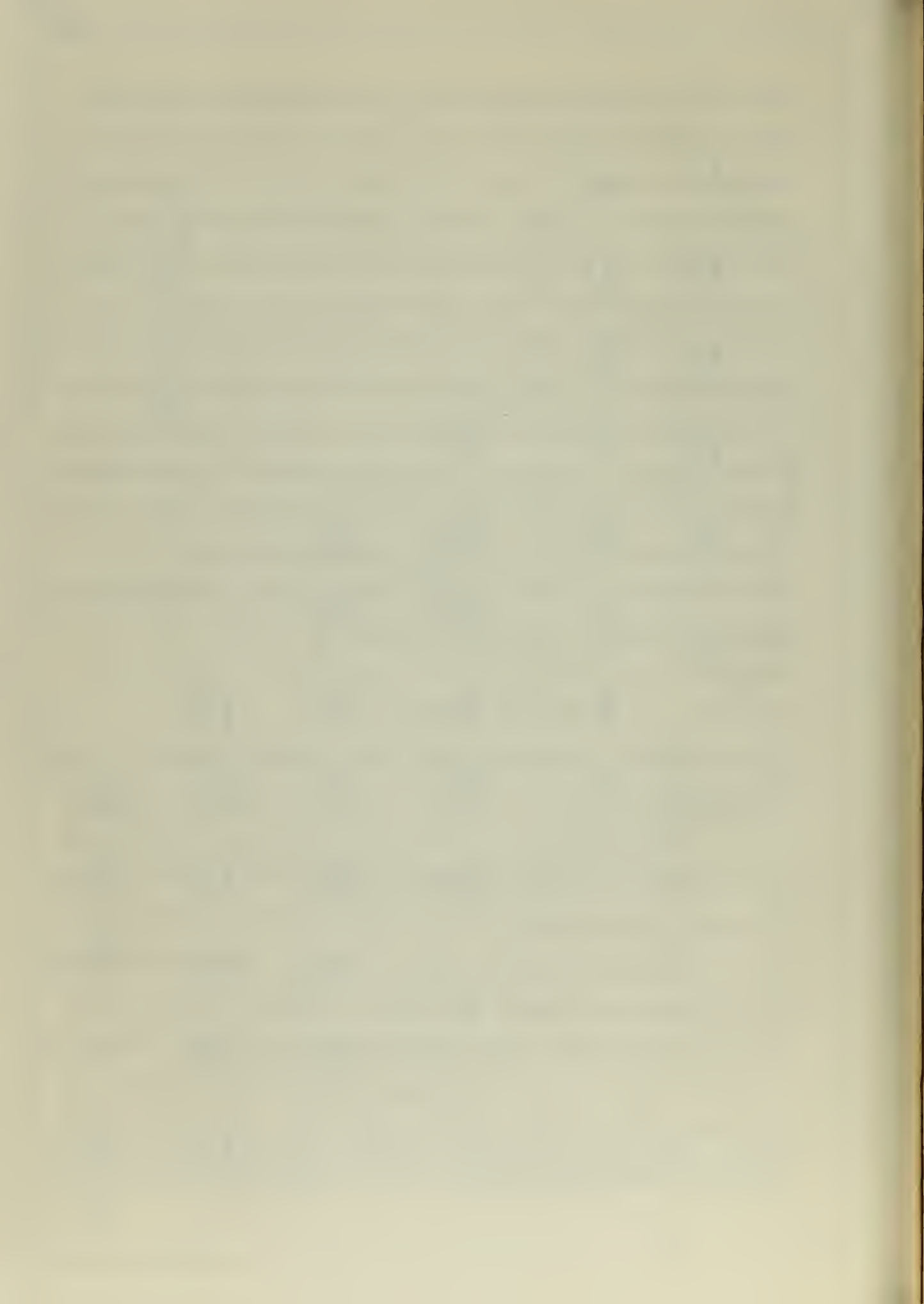


Figure 5. Pressures by Block Areas



If natural gas expanded upon release in pressure exactly in accordance with Boyle's law, the pressure decline curve would merely be a straight line through the original reservoir pressure and the May 31, 1954 reservoir pressure plotted against cumulative production as of May 31, 1954. However, since natural gas does not conform exactly to Boyle's law, the compressibility factor had to be considered. Calhoun shows that reservoir pressure (P) divided by the compressibility factor for the gas (Z) at reservoir conditions will plot as a straight line against cumulative production.¹¹ Compressibility factors were, therefore, computed for the two above reservoir pressures as shown in Appendix II and a straight line plot made between the two P/Z points thus determined. The accuracy of the curve was checked analytically, also as shown in Appendix II. The reservoir pressures as they would be measured both in the reservoir and at the surface (Figure 4) were computed from the P/Z curve, using compressibility factors and values for the pressure due to the weight of the gas column as are shown graphically in Figures 7 and 8, Appendix II.

The 239 billion standard cubic feet of gas, as calculated to have been originally in the reservoir, at first appeared high, considering the present low production rate from the wells. An additional calculation was, therefore, made to determine the porosity of the sand, using 42,000 acres which has been estimated as the area of the reservoir, and an average sand thickness of 17 feet as estimated from the few well records showing this information. The porosity thus calculated, as shown in Appendix II came to 4.18 per cent. This porosity certainly does not appear to be excessive, considering the nine per cent and 8.34 per cent porosities found, respectively, for Oriskany sand samples blown from wells in the Tioga¹² and the Leidy gas fields.¹³

It cannot be expected that relief in present conditions is

possible at the present time, the present condition being such as to

enable him to do so. The original intention was to do so.

The present condition is such as to enable him to do so.

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In consideration of the above, the 289 billion cubic feet does not appear to be excessive. An additional similar calculation of reserves was made, however, using the absolute minimum feasible pressures for block areas as of May 31, 1954. This calculation showed 255 billion standard cubic feet as the original gas content of the reservoir. The original calculation is considered to be the more accurate.

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V. OPERATIONS

A. Determination of Average Well Productive Capacity

1. Bureau of Mines Equation

The Bureau of Mines has reported¹⁴ that:

"For normal gas wells there is a consistent relationship between rates of delivery of gas and corresponding pressures when the pressures in the sand are used as the basis for interpretation. Results of tests throughout the United States show that when the rates of delivery are plotted on logarithmic paper against $(P_f^2 - P_s^2)$ - the respective differences of the squares of the formation pressure, P_f , and the pressure at the sand face, P_s - the relationship is represented by a straight line, which may be expressed mathematically by the formula

$$Q = C(P_f^2 - P_s^2)^n$$

where Q = rate of flow, M cubic feet per 24 hours,

C = coefficient,

P_f = "shut-in" formation pressure, pounds per square inch absolute,

n = exponent, corresponding to the slope of the straight line relationship between Q and $(P_f^2 - P_s^2)$ plotted on logarithmic paper."

It is further pointed out in that report¹⁵ that the value of n , or the slope of the logarithmic plot, would remain constant if no physical changes occurred in the well bore or in the producing formation which affected the productive capacity of the well.

This Bureau of Mines report recommends the above relationship as a means for analyzing the deliverability of gas wells. The procedure involves, essentially, the periodic shutting in of the well to determine the formation pressure (P_f), and then permitting the well to flow at decreasing back pressures (P_s) during which time the rate of flow (Q) is measured

for each back pressure. The logarithmic plot described above can be extrapolated to determine the open flow capacity of the well without the necessity of venting the well to the atmosphere and thereby wasting gas and probably damaging the well.¹⁶ When flow rates so determined at periodic intervals fail to fall on the same straight-line logarithmic plot, it is indicative of changes occurring in the well or the producing formation, such as water coning, water condensation, well caving, etc. This procedure also provides a means for predicting flow rates at various back pressures and formation pressures, and for analyzing the effects of measures taken to increase a well's productive capacity.

A Bureau of Mines report¹⁷ some nine years later carried an interesting discussion of the value of n as related to a similar exponent in an equation¹⁸ for isothermal flow derived and confirmed experimentally by Muskat and Botset, where the latter had shown, in effect, that the value of n in the equation $Q = C(P_f^2 - P_s^2)^n$ would range from 0.5 for wholly turbulent flow to 1.0 for wholly viscous flow. The Bureau of Mines report stated that it had been shown experimentally that the value of n ranged from 0.6 to 1.2 and that there was no significant bending of the logarithmic plot toward the pressure axis for increased values of $(P_f^2 - P_s^2)$ and Q , as might have been expected.

It is significant to note, however, that the second Bureau of Mines report was based largely on results of tests set forth in the first report and that both field and experimental results¹⁹ were obtained from highly permeable sands through which gas was flowing under relatively low pressures. It is further significant to note that many laboratory tests did show logarithmic plots that bent slightly toward the pressure axis with increasing values of Q and $(P_f^2 - P_s^2)$, and that there appears to be

The first part of the paper is devoted to a discussion of the
 problem of the existence of a solution of the system of
 equations (1) and (2) for arbitrary values of the
 parameters α and β . It is shown that the system has a
 solution for all values of the parameters α and β if
 the function $f(x)$ is continuous and has a bounded
 derivative. The second part of the paper is devoted to
 the study of the properties of the solution of the
 system of equations (1) and (2) for arbitrary values of
 the parameters α and β . It is shown that the solution
 of the system of equations (1) and (2) is unique and
 depends continuously on the parameters α and β . The
 third part of the paper is devoted to the study of the
 properties of the solution of the system of equations (1)

no confirmation in laboratory tests for values of n greater than one. One might, therefore, surmise that possibly there could be a significant bending of the logarithmic curve toward the pressure axis with greatly increasing values of $(P_f^2 - P_g^2)$ and Q and that possibly the few cases during field tests where the value of n exceeded one resulted from physical changes occurring in the well bore or from inaccurate data. It is the author's opinion that values of n greater than one should be accepted with reservations, if at all.

2. Application of the Bureau of Mines Equation

The equation $Q = C(P_f^2 - P_g^2)^n$ as previously described is also applicable to groups of wells.²⁰ The average well productive capacity coefficient C , may therefore be obtained by averaging the C 's computed for each well by dividing Q by $(P_f^2 - P_g^2)^n$. Values for Q and for P_f as measured at the well head are shown in Appendix I. Since the value of n was not known, it was necessary to average the production rates (Q) for wells producing under the same $(P_f^2 - P_g^2)$. Further, since little confidence could be placed in the accuracy of the lower pressures, it was decided to use wells showing well-head pressures near 3500 pounds per square inch. Thirty such wells showed an average Q of 7300 M cubic feet per day. The pressure due to the weight of the column of gas in these wells averaged about 500 pounds per square inch, bringing the P_f value to 4000 pounds per square inch. Since P_g can be neglected for these large-hole high-pressure wells flowing against atmospheric pressure, 7300 (Q) can be plotted against 16,000,000 ($P_f^2 - P_g^2$) on logarithmic paper as is shown by point A in Figure 6. This gives one point on the logarithmic plot, but does not of course show the slope of the line which can be used to determine values of Q at different values of $(P_f^2 - P_g^2)$. It was decided to use an n value of one (viscous flow) in order to simplify calculations and to preclude the exaggeration

It is all.

[illegible]

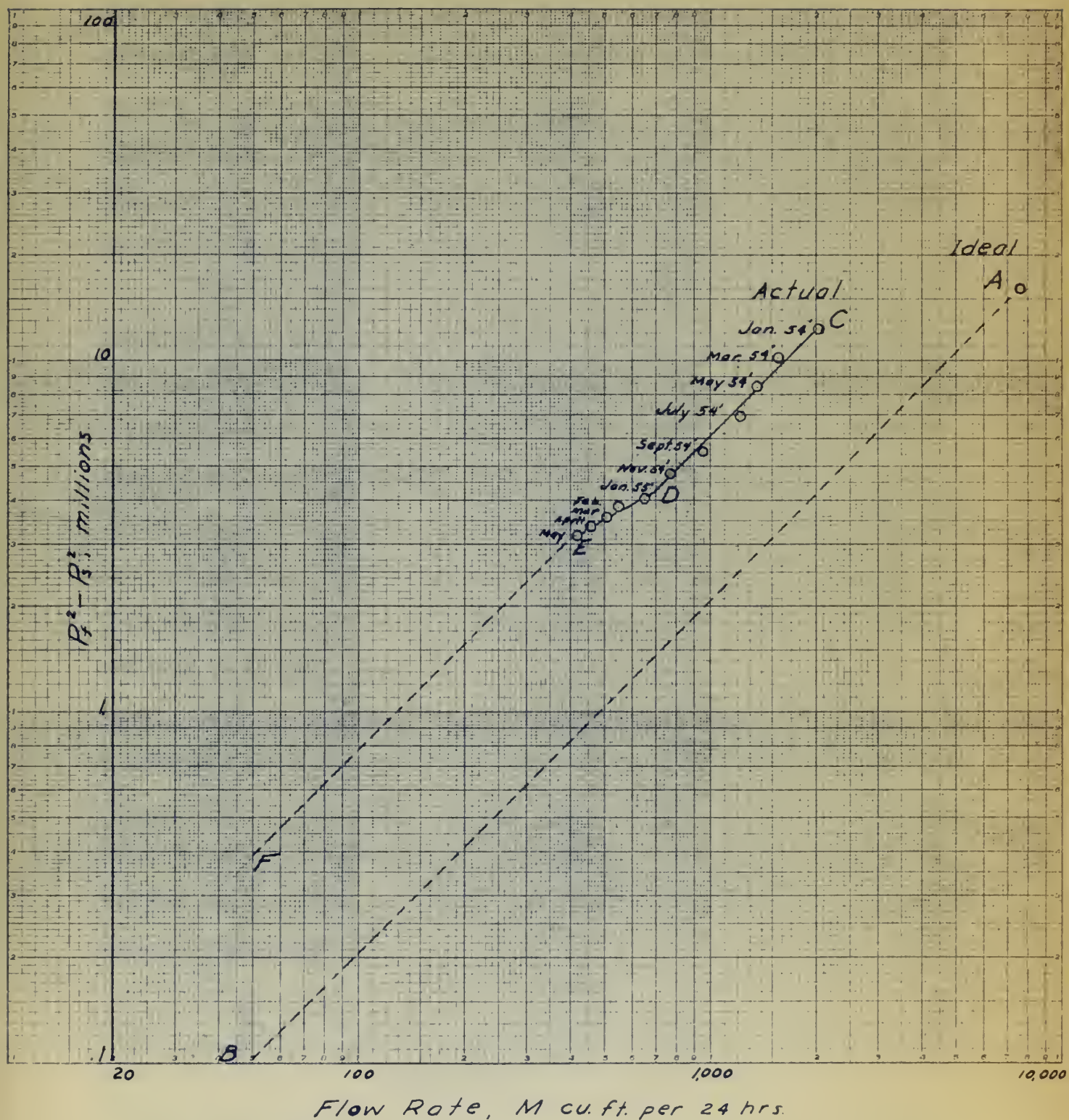


Figure 6. Average Well Flow Rate Decline

of the adverse effects of production practices as is brought out in Section V, B and C. Using this n value of one, the coefficient (C) for the 30 wells came to .456. These values of C and n were justified by an average value of C equal to .45 for 127 wells on which the recorded data appeared to be the most accurate. The value of C for each individual well in this case was obtained by dividing the flow rate (Q) by $(P_f^2 - P_g^2)$, P_f being the closed-in individual well-head pressure plus the pressure caused by the weight of the gas column, and P_g again neglected.

Readers might be interested in the calculation of average permeability as shown in Appendix II where the value of C equal to .456 was substituted in the Darcy's law radial flow equation for viscous flow. Though a rough assumption had to be made for the drainage radius and though the flow may not be considered as radial in all cases, the computed permeability of 4.05 millidarcies as compared to the estimated permeability of ten millidarcies tends to substantiate the assumption that the value of C is not excessive. Two samples blown from wells in the Laidy gas field averaged 10.9 millidarcies.²¹

In consideration of the above, the curve AB in Figure 6 may be considered to represent the production rate that could have been expected from the average well with decreasing values of $(P_f^2 - P_g^2)$ had the physical characteristics of the well and the producing formation remained constant, and had the wells been so spaced as to have the average formation pressure acting on each well.

B. Effect of Well Spacing and Production

Practices on Production Rate

As pointed out in the previous section, curve AB (Figure 6) represents the declining production rates with declining $(P_f^2 - P_g^2)$ values that could have been expected from average, undamaged, properly spaced wells. Curve CD (Figure 6) represents the actual average production rate per well with declining average reservoir pressures as shown in Figure 4. Points on curve CD were determined by dividing the total monthly production rates (Appendix III) by the average number of producing wells as of the date indicated (Appendix IV) and plotting these rates per well against the $(P_f^2 - P_g^2)$, P_f being considered as the formation pressure shown by Figure 4 and P_g being estimated as 600 pounds per square inch. The deficiency in production rate per well for any value of $(P_f^2 - P_g^2)$ is represented by the horizontal distance between the two curves. This loss can be attributed to local pressure depletions in densely drilled areas and to physical damage to wells brought on by the rapid production rate.

Losses in production rate resulting from dense well spacing and consequent local pressure depletions can be well illustrated by considering areas F, G, and H in Figure 2, where on May 31, 1954 some 73 wells were producing under a formation pressure of about 1700 pounds per square inch. If the back pressure at the sand face was 600 pounds per square inch, the production rate per well expressed as a per cent of the production rate which would have been attained under the average reservoir pressure of 2895 pounds per square inch at that time was

$$\frac{(1700^2 - 600^2)(100)}{(2895^2 - 600^2)} = 31.5 \text{ per cent}$$

Actually the formation pressure acting on many of the wells was probably considerably less than the average for the area. It is therefore obvious

that a well drilled in this area at that time produced gas at less than one-third the rate that could have been expected of it had unit operation been in effect, or that the same total production rate for this area could have been achieved with less than one-third of the wells.

Production losses caused by water coning, well caving, etc. cannot be well illustrated from the data available, although it would be a simple procedure to shut in wells occasionally and to plot the Q versus the $(P_f^2 - P_g^2)$ on logarithmic paper. A line through successive points thus obtained would indicate whether or not a well is being damaged. A curve that bent toward the pressure axis would be indicative of water coning or other factors hindering deliverability. If only two points are available, and a line through the two points has a slope greater than one (more than 45 degrees to the pressure axis), it will, in the author's opinion, be a positive indication of well damage. This procedure was attempted for the few state wells on which records could be found showing shut-in pressures sometime after their original gaging. However, curves thus obtained only served to prove the inadequacy and insecurity of recorded data. One curve showed a reverse slope, indicating lower flow rate with increasing formation pressure.

The Bureau of Mines back-pressure method for analyzing the deliverability of gas wells, as described briefly in Section V, A is a much more thorough and detailed procedure than that described above. Far greater benefits than that discussed above may also be derived from their method, although it requires the restricting of a well's flow for considerably more time than production practices in Pennsylvania permit.

THESE ARE THE RESULTS OF THE RESEARCH CONDUCTED BY THE
INSTITUTE OF MATHEMATICS OF THE ACADEMY OF SCIENCES OF THE
USSR IN THE FIELD OF THE THEORY OF THE STABILITY OF
EQUILIBRIUM POSITIONS OF MECHANICAL SYSTEMS. THE RESULTS
OBTAINED ARE PRESENTED IN THE FORM OF A MONOGRAPH
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The Bureau of Indian Affairs is aware of the fact that the
 Indian population of the United States is decreasing rapidly, and
 that the Government is responsible for the education and
 civilization of the Indian people. It is the policy of the
 Government to provide for the education of the Indian children
 in the boarding schools, and to provide for the education of the
 Indian adults in the day schools. The Bureau of Indian Affairs
 is also responsible for the distribution of the Indian lands,
 and for the management of the Indian affairs.

C. Estimated Losses in Ultimate Recovery

Although it is impossible to predict the ultimate gas recovery from this reservoir with any degree of accuracy, it is fairly obvious in view of the declining production rate that an uneconomical production rate will be reached long before 239 billion cubic feet of gas have been produced.

Curve EF, Figure 6, shows a recent increasing rate of decline in production rate. This may be due to a variety of factors, such as

1. Water fingering cutting off relatively high pressure gas zones.
2. Water coning near the well bore, reducing the effective sand thickness.
3. Water condensation, reducing the effective permeability to the gas.
4. Well caving
5. Structural conditions within the reservoir.
6. The temporary shutting in of an increasing number of wells (since the rate is based on the number of producing wells as drilled rather than the actual number in operation).
7. Almost total pressure depletion in densely drilled areas.

It is the author's opinion, however, that conditions in the reservoir may soon stabilize and that the flow rate after that time will continue in a directly proportional relationship with $(P_f^2 - P_s^2)$; at least this is the best that can be expected. This is illustrated by the curve EF, Figure 6. Though there is little chance that this curve will hold true to the abandonment date, it is not unreasonable to expect that it will hold approximately true for the next few years. This curve may be used in conjunction with the reservoir pressure curve (Figure 4) to

J. L. B. & J. L. B.

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From this receipt and the degree of exposure, it is fairly certain that the material was not in contact with the material in the container.

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DOI: 10.1177/1053426902238483
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...and the ...

1. Labor Expenditure Control will minimize the cost of the project.

എല്ലാവർക്കും കർമ്മ പ്രവർത്തികൾക്കും പരമമായി ഉപയോഗിക്കാവുന്ന ഒരു പുസ്തകം ആണ് ഇത്. അതിനാൽ ഇത് എല്ലാവർക്കും വേണ്ടി പ്രസിദ്ധീകരിച്ചിരിക്കുന്നു.

2. "After consulting the relevant documents, the Commission has concluded that the information provided by the applicant is reliable and that the applicant is a person of good character and is not a member of any organization which is prohibited by law."

It is further recommended that the following be added to the list of persons to be interviewed:

1. The first step is to identify the problem or question that needs to be answered. This involves understanding the context and the specific requirements of the task.

It is the author's opinion, however, that attention to the review

Very truly yours,
 J. Edgar Hoover

There is a linear relationship with \log_{10} of time

2022 is the last year that can be reported. Data is projected for the years 2023 and 2024.

17. *Figure 2. There is little reason that this issue will solve*

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with both approaches, the results are similar. The results are similar to those reported in the literature for the case of a single input.

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provide a trial and error means for predicting future production and production rates. The dotted portions of the curves (Figure 3) were derived in this manner, considering a gradually decreasing value of P_g to zero in the year 1959. By the end of the year 1959 there should have been about 240 billion cubic feet of gas produced from this reservoir.

In consideration of curves AB and EF (Figure 6) and assuming a minimum economic flow rate (Q) of 50 MCF per day at zero back pressure (P_g), the reservoir could be expected to be abandoned at an average pressure (P_f) of 632 pounds per square inch, whereas in the "ideal" case the abandonment pressure would be 316 pounds per square inch. This, according to Figure 4, reflects a loss of about 22 billion cubic feet of gas due to inefficient production practices.

Actually, it is anyone's guess as to just how far into the future this reservoir will produce gas at an economic rate. Most likely there will be numerous wells capable of producing gas at an economic rate for many years to come. It is highly probable, however, that water fingering and coning has or will cut off relatively high pressure zones within the reservoir, and that a reduced effective permeability to gas caused by water coning and condensation will seriously curtail production and reduce the ultimate recovery. An estimated loss of approximately 20 billion cubic feet of gas is considered to be conservative.

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VI. EVALUATION OF RESULTS

A. Operational Aspects

Although this study has developed no absolute proof that there will be substantial losses in ultimate recovery of gas from this reservoir, it does indicate that such losses are very likely and presents definite proof that a great amount of manpower and materials have been unnecessarily expended. Curves AB and CD (Figure 6) show that actual production per well was only about 35 per cent of what might have been expected from the properly-spaced average well, or that about one-third of the wells, if properly spaced and undamaged, should have given the same production rate. As was pointed out in Section V, A, 2, this figure is based on a conservative estimate of the slope of the logarithmic curve AB (Figure 6) equal to one. It is possible that this curve could have had a slope of less than one, showing an increasingly wide separation between the "ideal" and "actual" curves with decreasing pressures, and therefore an increasingly poorer comparison of the actual well production rate with that of the ideal.

The ideal number of wells can only be determined by an economic balance of a great many factors, such as recoverable gas in place, drilling costs, back pressure required to prevent damaging the well or the producing formation, market demands and commitments and others. The back pressure required can be determined accurately by the Bureau of Mines method, but even this is subject to economic considerations. It may, for example, be more economical to permit minor damage to the well than to hold the back pressure sufficiently high to prevent damage entirely. Some states force the application of back pressure by restricting gas

the land is not to be sold until the same is surveyed.

It is the policy of the Government to sell the land in small tracts, and to sell the same at a low price, so that the people may be able to purchase the same.

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production to 25 per cent of open flow capacity. However, this restriction is also intended to prevent gas production in excess of market demands, and there is no reason known to the author why Pennsylvania should restrict production to this rate if it can be shown that significant damage will not occur to wells producing at higher capacities. All of the above factors can best be weighed and applied through a unit operation plan, assisted perhaps by a well-spacing regulation.

It is probable that no more than two billion cubic feet per month would have been the ideal production rate from the Briftwood-Benezette field. Gas companies taking gas from this field must contract for vast quantities of gas from the Southwest to meet commitments during the winter months. Furthermore, the nature of pipeline operations as well as economic factors in the producing Southwest demand the establishment of long-term contracts with little or no seasonal variations in gas deliveries. This requires the delivery of large quantities of gas to this area during the summer months which must be stored in underground reservoirs. It is therefore obvious that the most economical rate to extract gas from this field would be a long-term rate necessary to augment deliveries from the Southwest with a minimum of storing required.

According to curve AB (Figure 6), two billion cubic feet per month could have been produced early in the productive life of the field ($P_f = 4600$) with 27 wells producing at 25 per cent of open-flow capacity, and with 100 wells at this capacity five years later when the 120 billion cubic feet produced would have caused the reservoir pressure to drop to about 2400 pounds per square inch (Figure 4). At 50 per cent open-flow capacity, only half of these wells would be required, and 100 wells would produce two billion cubic feet or more per month until 175 billion cubic

[illegible]

It is important to note that the results of this study are based on a cross-sectional design, which limits the ability to establish causality. Future research should employ longitudinal designs to investigate the temporal relationships between the variables studied.

the Government of the United States of America, Department of the Interior, Bureau of Land Management, is hereby notified that the following land is being offered for sale:

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1. The first step in the process is to identify the problem. This involves gathering information about the situation and determining what needs to be done. Once the problem is identified, the next step is to develop a plan. This involves deciding on the best way to solve the problem and setting a timeline for completion. Once the plan is developed, the next step is to implement it. This involves putting the plan into action and monitoring progress. Finally, the last step is to evaluate the results. This involves assessing the effectiveness of the solution and determining if any further action is needed.

feet of gas had been produced. Assuming that the flow rate could reach a maximum at the lower pressures without causing significant damage to the wells or the formation, 100 wells would sustain the 2 billion cubic feet per month rate for almost nine years or until 210 billion cubic feet of gas had been produced. Does not this appear more efficient and logical than has been the actual practice of drilling 277 producing wells, with more to come, to obtain the flow rate shown in Figure 3?

The above comparison of actual practices with those which might have been employed under unit operations or under well spacing regulations does not show a comparison of ultimate recovery losses. It was illustrated in Section V, C that there should be at least 20 billion cubic feet of gas lost because of inefficient production practices. Though structural conditions in the reservoir might not permit such high ultimate recovery in either the actual or the ideal case, it is probable that unit operations or adequate well spacing regulations would provide for more efficient exploration and thereby for a production rate closely approaching that shown by the curve AB (Figure 6).

It is estimated that about 75 billion cubic feet of gas would have been lost in the field by at least ten years ago had it been possible to produce gas at a maximum rate of 2 billion cubic feet per month. This would mean that the total gas production would be 210 billion cubic feet.

There have been numerous relatively minor economic studies made, such as expenses for operating equipment, additional well construction costs and so on. But production practices, which involve the largest costs, have not been studied.

In view of the foregoing discussion, it is recommended that a study be made of the production practices employed in the oil and gas fields. Furthermore, a large

1. The first step in the process of identifying a problem is to define the problem. This involves identifying the symptoms of the problem and determining the scope of the problem. Once the problem has been defined, the next step is to identify the causes of the problem. This involves identifying the factors that are contributing to the problem and determining the underlying causes. Once the causes have been identified, the next step is to develop a plan of action. This involves identifying the steps that need to be taken to solve the problem and determining the resources that will be needed to implement the plan. Finally, the last step in the process is to implement the plan and monitor the results. This involves putting the plan into action and tracking the progress of the solution. Once the problem has been solved, the final step is to evaluate the results and determine if the solution was effective. This involves comparing the results of the solution to the original problem and determining if the problem has been solved. If the problem has not been solved, the process may need to be repeated.

the court's decision in *United States v. Gaudin*, 117 F.3d 1047 (9th Cir. 1997), which held that the government's failure to disclose the results of its forensic analysis of the defendant's fingerprints was a material omission under the Brady rule. The court in *Gaudin* found that the government's failure to disclose the results of its forensic analysis of the defendant's fingerprints was a material omission under the Brady rule, and that the defendant's conviction was therefore reversed.

B. Economic Aspects

1. General

The economic aspects of production practices may be illustrated roughly as follows:

(a) Before this reservoir is abandoned there will probably have been 300 producing wells drilled -- 200 more than is conservatively estimated to be the ideal as stated in the previous section. At \$75,000 per well, this will amount to an unnecessary expenditure of \$15,000,000.

(b) It is estimated that at least 60 billion cubic feet of gas will have been stored and re-extracted beyond that which would have been necessary at the two billion per month rate. At an estimated cost of five cents per thousand cubic feet for storing and re-extracting, this will amount to \$3,000,000.

(c) Twenty billion cubic feet of gas estimated to be lost due to open flow production practices, at an estimated net value of about ten cents per M cubic feet²² will amount to a loss of \$2,000,000.

(d) It is estimated that about 75 billion cubic feet of gas would have increased in value by at least two cents per M cubic feet had it been possible to produce this gas on a seasonal contract or at a slower rate. This will amount to \$1,500,000.

(e) There have been numerous relatively minor excessive expenditures, such as expenses for operating compressor stations, additional well maintenance costs due to open flow production practices, excess gathering lines, etc.

In view of the foregoing illustration, it is reasonable to assume that \$20,000,000 have or will be wasted by the production practices employed in the Driftwood-Benezette gas reservoir. Furthermore, a large

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In view of the foregoing illustration, it is reasonable to assume

that \$20,000,000 have or will be wasted by the production practices em-

ployed in the Driftwood-Benezette gas reservoir. Furthermore, a large

portion of these losses will be paid by the consumer in the form of high gas prices or in taxes to make up for the losses from state-owned tracts.

2. Private Landowners

Much of the land overlying this reservoir is privately owned small tracts of one acre or less. Such a landowner's fair share of the gas, considering 40,000 acres total and 280 billion cubic feet of gas as recoverable, is 7,000 M cubic feet. At one-eighth royalty this figure is further reduced to roughly 900 M cubic feet, which would amount to \$247.50 at the current price of 27½ cents per M cubic feet. It is conservatively estimated that many small tract landowners have or will receive at least a hundred times this figure. Their excess profits obviously resulted in losses from less densely drilled areas, which in this field are mostly state-owned tracts.

12

position of these houses will be held by the company in the case of high
low prices or in case of sale of the houses from estate to estate.

5. Future business

Part of the land owned by the company is presently used

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VII. CONCLUSIONS AND RECOMMENDATIONS

It is concluded that there have been about 200 excess wells drilled in the Briftwood-Senezette field; that there could not possibly have been a fair and equitable distribution of the gas among the various landowners; that very probably there have or will be large quantities of gas left in the reservoir because of open-flow production practices; that sound engineering principles are not observed in gaging wells and in evaluating their performance, and that all of these are directly attributable to the lack of petroleum regulatory statutes in Pennsylvania. It is further concluded that the general public supports a large share of the inequities, gas losses and excess expenses either in higher gas prices or in decreased revenue from publicly owned land.

The obvious recommendation, therefore, is that the citizens of Pennsylvania demand the enactment of state statutes which will prevent this waste of manpower, materials, and petroleum resources, and which will insure the protection of correlative rights of landowners.

The details of the varied petroleum conservation measures and unitization statutes are beyond the scope of this paper. The average citizen, however, should not be so much concerned with these details as by the fact that nothing is being done to remedy the current inefficient and unfair production practices. Citizens should place their faith in an Oil and Gas Commission appointed for the purpose of recommending appropriate conservation and unitization statutes and for enforcing the statutes after they are enacted. No person need fear monopolistic practices or the deprivation of his property without the due process of law. He is protected from these under federal law.

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It is available on tape at government information centers.

It is the policy of the Department of the Interior to maintain the public lands in a state of preservation and to protect the same from unauthorized use and disposal. The Department is also authorized to lease the public lands for the purpose of grazing, mining, and other uses, and to regulate the same in accordance with the public interest.

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and the fact that the Government has been unable to obtain the necessary information to make a proper assessment of the situation in the country, it is not possible to make a proper assessment of the situation in the country.

Information is hereby notified that the Government of the United States of America is not responsible for the content or accuracy of this information.

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WASHINGTON, D. C. 20315

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and the other two are the same as the first two.

It is additionally recommended that the State immediately institute a program to acquire, compile and correlate information needed for accurate engineering studies, and to make this information readily available to all interested parties. No information relating to well production should be confidential. The very least that should be done is the enactment of a law requiring that all gas wells be shut in for a minimum of 48 hours once a year and that shut-in pressures be recorded and reported to an appropriate state regulatory body. Open-flow capacities, or flow rates against stated back pressures, should be recorded at the time wells are shut in, and likewise reported. Though this information will not suffice for accurate computation of the wells' performance by the Bureau of Mines back-pressure method, it will provide for considerably more accurate engineering studies than are currently possible. This recommendation would be superfluous if adequate petroleum conservation laws were enacted, for effective conservation presupposes a requirement for accurate knowledge of both the gas reservoir and the producing wells, which can only be gained from extensive and accurate data.

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APPENDIX I

FINANCIAL DATA ON THE JOINTLY-OWNED AND MANAGED

Year	Operating Income	Depreciation	Amortization	Total
1951	1,000,000	100,000	50,000	1,150,000
1952	1,200,000	120,000	60,000	1,380,000
1953	1,400,000	140,000	70,000	1,610,000
1954	1,600,000	160,000	80,000	1,840,000
1955	1,800,000	180,000	90,000	2,070,000
1956	2,000,000	200,000	100,000	2,300,000
1957	2,200,000	220,000	110,000	2,530,000
1958	2,400,000	240,000	120,000	2,760,000
1959	2,600,000	260,000	130,000	2,990,000
1960	2,800,000	280,000	140,000	3,220,000
1961	3,000,000	300,000	150,000	3,450,000
1962	3,200,000	320,000	160,000	3,680,000
1963	3,400,000	340,000	170,000	3,910,000
1964	3,600,000	360,000	180,000	4,140,000
1965	3,800,000	380,000	190,000	4,370,000
1966	4,000,000	400,000	200,000	4,600,000
1967	4,200,000	420,000	210,000	4,830,000
1968	4,400,000	440,000	220,000	5,060,000
1969	4,600,000	460,000	230,000	5,290,000
1970	4,800,000	480,000	240,000	5,520,000
1971	5,000,000	500,000	250,000	5,750,000
1972	5,200,000	520,000	260,000	5,980,000
1973	5,400,000	540,000	270,000	6,210,000
1974	5,600,000	560,000	280,000	6,440,000
1975	5,800,000	580,000	290,000	6,670,000
1976	6,000,000	600,000	300,000	6,900,000
1977	6,200,000	620,000	310,000	7,130,000
1978	6,400,000	640,000	320,000	7,360,000
1979	6,600,000	660,000	330,000	7,590,000
1980	6,800,000	680,000	340,000	7,820,000
1981	7,000,000	700,000	350,000	8,050,000
1982	7,200,000	720,000	360,000	8,280,000
1983	7,400,000	740,000	370,000	8,510,000
1984	7,600,000	760,000	380,000	8,740,000
1985	7,800,000	780,000	390,000	8,970,000
1986	8,000,000	800,000	400,000	9,200,000
1987	8,200,000	820,000	410,000	9,430,000
1988	8,400,000	840,000	420,000	9,660,000
1989	8,600,000	860,000	430,000	9,890,000
1990	8,800,000	880,000	440,000	10,120,000
1991	9,000,000	900,000	450,000	10,350,000
1992	9,200,000	920,000	460,000	10,580,000
1993	9,400,000	940,000	470,000	10,810,000
1994	9,600,000	960,000	480,000	11,040,000
1995	9,800,000	980,000	490,000	11,270,000
1996	10,000,000	1,000,000	500,000	11,500,000
1997	10,200,000	1,020,000	510,000	11,730,000
1998	10,400,000	1,040,000	520,000	11,960,000
1999	10,600,000	1,060,000	530,000	12,190,000
2000	10,800,000	1,080,000	540,000	12,420,000
2001	11,000,000	1,100,000	550,000	12,650,000
2002	11,200,000	1,120,000	560,000	12,880,000
2003	11,400,000	1,140,000	570,000	13,110,000
2004	11,600,000	1,160,000	580,000	13,340,000
2005	11,800,000	1,180,000	590,000	13,570,000
2006	12,000,000	1,200,000	600,000	13,800,000
2007	12,200,000	1,220,000	610,000	14,030,000
2008	12,400,000	1,240,000	620,000	14,260,000
2009	12,600,000	1,260,000	630,000	14,490,000
2010	12,800,000	1,280,000	640,000	14,720,000
2011	13,000,000	1,300,000	650,000	14,950,000
2012	13,200,000	1,320,000	660,000	15,180,000
2013	13,400,000	1,340,000	670,000	15,410,000
2014	13,600,000	1,360,000	680,000	15,640,000
2015	13,800,000	1,380,000	690,000	15,870,000
2016	14,000,000	1,400,000	700,000	16,100,000
2017	14,200,000	1,420,000	710,000	16,330,000
2018	14,400,000	1,440,000	720,000	16,560,000
2019	14,600,000	1,460,000	730,000	16,790,000
2020	14,800,000	1,480,000	740,000	17,020,000
2021	15,000,000	1,500,000	750,000	17,250,000
2022	15,200,000	1,520,000	760,000	17,480,000
2023	15,400,000	1,540,000	770,000	17,710,000
2024	15,600,000	1,560,000	780,000	17,940,000
2025	15,800,000	1,580,000	790,000	18,170,000
2026	16,000,000	1,600,000	800,000	18,400,000
2027	16,200,000	1,620,000	810,000	18,630,000
2028	16,400,000	1,640,000	820,000	18,860,000
2029	16,600,000	1,660,000	830,000	19,090,000
2030	16,800,000	1,680,000	840,000	19,320,000
2031	17,000,000	1,700,000	850,000	19,550,000
2032	17,200,000	1,720,000	860,000	19,780,000
2033	17,400,000	1,740,000	870,000	20,010,000
2034	17,600,000	1,760,000	880,000	20,240,000
2035	17,800,000	1,780,000	890,000	20,470,000
2036	18,000,000	1,800,000	900,000	20,700,000
2037	18,200,000	1,820,000	910,000	20,930,000
2038	18,400,000	1,840,000	920,000	21,160,000
2039	18,600,000	1,860,000	930,000	21,390,000
2040	18,800,000	1,880,000	940,000	21,620,000
2041	19,000,000	1,900,000	950,000	21,850,000
2042	19,200,000	1,920,000	960,000	22,080,000
2043	19,400,000	1,940,000	970,000	22,310,000
2044	19,600,000	1,960,000	980,000	22,540,000
2045	19,800,000	1,980,000	990,000	22,770,000
2046	20,000,000	2,000,000	1,000,000	23,000,000
2047	20,200,000	2,020,000	1,010,000	23,230,000
2048	20,400,000	2,040,000	1,020,000	23,460,000
2049	20,600,000	2,060,000	1,030,000	23,690,000
2050	20,800,000	2,080,000	1,040,000	23,920,000
2051	21,000,000	2,100,000	1,050,000	24,150,000
2052	21,200,000	2,120,000	1,060,000	24,380,000
2053	21,400,000	2,140,000	1,070,000	24,610,000
2054	21,600,000	2,160,000	1,080,000	24,840,000
2055	21,800,000	2,180,000	1,090,000	25,070,000
2056	22,000,000	2,200,000	1,100,000	25,300,000
2057	22,200,000	2,220,000	1,110,000	25,530,000
2058	22,400,000	2,240,000	1,120,000	25,760,000
2059	22,600,000	2,260,000	1,130,000	25,990,000
2060	22,800,000	2,280,000	1,140,000	26,220,000
2061	23,000,000	2,300,000	1,150,000	26,450,000
2062	23,200,000	2,320,000	1,160,000	26,680,000
2063	23,400,000	2,340,000	1,170,000	26,910,000
2064	23,600,000	2,360,000	1,180,000	27,140,000
2065	23,800,000	2,380,000	1,190,000	27,370,000
2066	24,000,000	2,400,000	1,200,000	27,600,000
2067	24,200,000	2,420,000	1,210,000	27,830,000
2068	24,400,000	2,440,000	1,220,000	28,060,000
2069	24,600,000	2,460,000	1,230,000	28,290,000
2070	24,800,000	2,480,000	1,240,000	28,520,000
2071	25,000,000	2,500,000	1,250,000	28,750,000
2072	25,200,000	2,520,000	1,260,000	28,980,000
2073	25,400,000	2,540,000	1,270,000	29,210,000
2074	25,600,000	2,560,000	1,280,000	29,440,000
2075	25,800,000	2,580,000	1,290,000	29,670,000
2076	26,000,000	2,600,000	1,300,000	29,900,000
2077	26,200,000	2,620,000	1,310,000	30,130,000
2078	26,400,000	2,640,000	1,320,000	30,360,000
2079	26,600,000	2,660,000	1,330,000	30,590,000
2080	26,800,000	2,680,000	1,340,000	30,820,000
2081	27,000,000	2,700,000	1,350,000	31,050,000
2082	27,200,000	2,720,000	1,360,000	31,280,000
2083	27,400,000	2,740,000	1,370,000	31,510,000
2084	27,600,000	2,760,000	1,380,000	31,740,000
2085	27,800,000	2,780,000	1,390,000	31,970,000
2086	28,000,000	2,800,000	1,400,000	32,200,000
2087	28,200,000	2,820,000	1,410,000	32,430,000
2088	28,400,000	2,840,000	1,420,000	32,660,000
2089	28,600,000	2,860,000	1,430,000	32,890,000
2090	28,800,000	2,880,000	1,440,000	33,120,000
2091	29,000,000	2,900,000	1,450,000	33,350,000
2092	29,200,000	2,920,000	1,460,000	33,580,000
2093	29,400,000	2,940,000	1,470,000	33,810,000
2094	29,600,000	2,960,000	1,480,000	34,040,000
2095	29,800,000	2,980,000	1,490,000	34,270,000
2096	30,000,000	3,000,000	1,500,000	34,500,000
2097	30,200,000	3,020,000	1,510,000	34,730,000
2098	30,400,000	3,040,000	1,520,000	34,960,000
2099	30,600,000	3,060,000	1,530,000	35,190,000
2100	30,800,000	3,080,000	1,540,000	35,420,000

APPENDICES

*Total shown by column and rows in Tables 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100, 101, 102, 103, 104, 105, 106, 107, 108, 109, 110, 111, 112, 113, 114, 115, 116, 117, 118, 119, 120, 121, 122, 123, 124, 125, 126, 127, 128, 129, 130, 131, 132, 133, 134, 135, 136, 137, 138, 139, 140, 141, 142, 143, 144, 145, 146, 147, 148, 149, 150, 151, 152, 153, 154, 155, 156, 157, 158, 159, 160, 161, 162, 163, 164, 165, 166, 167, 168, 169, 170, 171, 172, 173, 174, 175, 176, 177, 178, 179, 180, 181, 182, 183, 184, 185, 186, 187, 188, 189, 190, 191, 192, 193, 194, 195, 196, 197, 198, 199, 200, 201, 202, 203, 204, 205, 206, 207, 208, 209, 210, 211, 212, 213, 214, 215, 216, 217, 218, 219, 220, 221, 222, 223, 224, 225, 226, 227, 228, 229, 230, 231, 232, 233, 234, 235, 236, 237, 238, 239, 240, 241, 242, 243, 244, 245, 246, 247, 248, 249, 250, 251, 252, 253, 254, 255, 256, 257, 258, 259, 260, 261, 262, 263, 264, 265, 266, 267, 268, 269, 270, 271, 272, 273, 274, 275, 276, 277, 278, 279, 280, 281, 282, 283, 284, 285, 286, 287, 288, 289, 290, 291, 292, 293, 294, 295, 296, 297, 298, 299, 300, 301, 302, 303, 304, 305, 306, 307, 308, 309, 310, 311, 312, 313, 314, 315, 316, 317, 318, 319, 320, 321, 322, 323, 324, 325, 326, 327, 328, 329, 330, 331, 332, 333, 334, 335, 336, 337, 338, 339, 340, 341, 342, 343, 344, 345, 346, 347, 348, 349, 350, 351, 352, 353, 354, 355, 356, 357, 358, 359, 360

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APPENDIX I

Producing Wells in the Driftwood-Benezette Gas Field

<u>Well No. and Area*</u>	<u>Name and Number</u>	<u>Drilling Completed</u>	<u>Depth</u>	<u>Flow Mcf/day</u>	<u>Initial W.H.P. psig</u>
1-A	S.C. Eaton, Jr. #1 (Sylv.)	9-15-51	5922	4,000	3925
11-N	Bearpaw Rod & Gum #1 (Fralich)	5-5-52	5376	4,900	3950
23-O	B & O #1 (Plymouth)	6-23-52	5952	80	-
25-A	Caldwell #1	7-9-52	5886	1,000	3500
29-A	Mix Run School Lot #1	7-25-52	5830	3,300	3950
36-N	J. W. Moate #1	8-18-52	6143	6,880	850
37-A	B. R. & G. #1 (Fox)	8-29-52	5802	3,200	2850
38-A	Caldwell #1	9-10-52	5846	700	-
41-A	Caldwell #2	10-3-52	5857	3,400	2700
43-O	McMillan Est. #1 (Delta)	10-10-52	5820	6,100	3400
45-O	S. C. Eaton #6	10-13-52	5996	3,500	3340
47-A	St. 2 Tr. 19	10-27-52	7051	1,000	3650
50-A	Moate #1 (Fox)	11-14-52	5862	1,200	3050
52-O	S. C. Eaton, Jr. #4	11-25-52	5903	838	2700
53-A	S. C. Eaton, Jr. #2 (Sylv)	12-3-52	6227	1,620	2500
54-N	St. 1 Tr. 20	12-8-52	5927	4,500	3655
55-O	S. C. Eaton, Jr. #2 (NYSH)	12-9-52	5944	2,100	2250
57-B	Charlton Mt. Club #1	12-30-52	6975	2,800	3810
58-N	St. 2 Tr. 20	12-31-52	6408	1,900	3200
59-A	S. Moate #1 (Panco)	1-2-53	5840	2,560	1775
60-A	S. Moate #2	1-2-53	5851	2,166	2925
61-O	Eaton #7	1-3-53	5822	2,274	2170
62-A	Brookbank #1	1-5-53	5887	3,100	3250
63-N	H. A. Moate #1 (Sylvania)	1-10-53	6072	177	660
64-B	H. L. Pearsall #1	2-2-53	5978	3,000	3400
65-A	H. A. Moate #2	2-18-53	5984	134	1520
66-N	Clyde L. Smith #1	2-20-53	6075	239	-
67-O	S. C. Eaton #5	2-20-53	5980	2,386	1805
69-F	Wm. Wadring #1	3-7-53	6153	713	800
72-F	W. A. Thurby #1	3-24-53	6101	8,000	4000
74-Q	Sagamore Hunt Club #1	4-1-53	6893	18,200	2150
75-B	Catherine Bartoletto #1	4-11-53	6134	9,500	3950
77-N	Eaton #8	4-21-53	6390	3,450	1740
79-S	Charlton Mt. Club #3	5-2-53	6936	17,000	-
80-N	Clyde Smith #2	5-14-53	6150	1,017	1310
81-N	Eaton #9	5-25-53	6810	2,600	1745
82-B	B & O #2	5-27-53	5870	1,200	1900
84-S	Charlton Mt. Club #2	6-1-53	6943	5,250	3300
85-R	Sagamore Hunt Club #1	6-2-53	6903	8,900	3675
86-S	Johanson Est. #1	6-3-53	6307	9,800	4020
88-B	St. 4 Tr. 19	6-10-53	6019	300	-
89-N	Moate #3	6-12-53	6592	1,038	1400
92-O	Charles Duell #1	6-20-53	6168	400	2860

*Wells shown by number and area in Figure 2. Missing numbers in the sequence indicate dry holes drilled in or near the field.

Year	Month	Day	Event	Location	Notes
1901	Jan	1	First day of school	St. Paul	
1901	Jan	15	St. Paul	St. Paul	
1901	Jan	30	St. Paul	St. Paul	
1901	Feb	1	St. Paul	St. Paul	
1901	Feb	15	St. Paul	St. Paul	
1901	Feb	28	St. Paul	St. Paul	
1901	Mar	1	St. Paul	St. Paul	
1901	Mar	15	St. Paul	St. Paul	
1901	Mar	31	St. Paul	St. Paul	
1901	Apr	1	St. Paul	St. Paul	
1901	Apr	15	St. Paul	St. Paul	
1901	Apr	30	St. Paul	St. Paul	
1901	May	1	St. Paul	St. Paul	
1901	May	15	St. Paul	St. Paul	
1901	May	31	St. Paul	St. Paul	
1901	Jun	1	St. Paul	St. Paul	
1901	Jun	15	St. Paul	St. Paul	
1901	Jun	30	St. Paul	St. Paul	
1901	Jul	1	St. Paul	St. Paul	
1901	Jul	15	St. Paul	St. Paul	
1901	Jul	31	St. Paul	St. Paul	
1901	Aug	1	St. Paul	St. Paul	
1901	Aug	15	St. Paul	St. Paul	
1901	Aug	31	St. Paul	St. Paul	
1901	Sep	1	St. Paul	St. Paul	
1901	Sep	15	St. Paul	St. Paul	
1901	Sep	30	St. Paul	St. Paul	
1901	Oct	1	St. Paul	St. Paul	
1901	Oct	15	St. Paul	St. Paul	
1901	Oct	31	St. Paul	St. Paul	
1901	Nov	1	St. Paul	St. Paul	
1901	Nov	15	St. Paul	St. Paul	
1901	Nov	30	St. Paul	St. Paul	
1901	Dec	1	St. Paul	St. Paul	
1901	Dec	15	St. Paul	St. Paul	
1901	Dec	31	St. Paul	St. Paul	

1. The first step is to identify the problem or question that needs to be answered. This involves understanding the context and the specific information required.

APPENDIX I (Continued)

Well No. and Area ^a	Name and Number	Drilling Completed	Depth	Flow Mcf/day	Initial W.H.P. psig
93-N	H. A. Moate #5	6-22-53	6040	1,473	-
94-N	H. A. Moate #4	6-22-53	6190	2,100	2575
96-F	Batemun #1	6-27-53	6112	16,980	3030
97-F	B & O RR #1 (Mid-Atlantic)	7-11-53	6087	12,250	3600
98-A	B & O #1 (Chs. Sample)	7-14-53	5880	4,500	2300
99-O	McMillian #1 (Kane)	7-22-53	5994	1,100	880
101-F	Theo. Sten #1	7-22-53	6065	8,500	3720
102-F	O. Johnson #1	7-23-53	6202	9,250	3750
103-K	Pearsall #1 (Fralich)	7-28-53	6974	25,500	3700
104-N	Van Voorhees #1 (Simon)	7-29-53	6099	9,600	3880
105-F	J. Miller #1	8-1-53	6048	7,000	3745
106-S	Charleroi #6	8-7-53	6218	2,700	3720
107-S	St. 4 Tr. 29	8-10-53	6870	2,075	3550
108-F	B. Johnson #1	8-11-53	6196	5,000	3020
109-F	P.R.R. #1	8-11-53	-	4,200	-
110-F	B. Johnson #2	8-11-53	6119	4,000	3170
111-F	J. Miller #2	8-14-53	6122	5,200	3000
112-F	Grafton (Camp Shanty) #1	8-14-53	6146	5,750	3000
113-A	H. A. Moate #6	8-14-53	6023	3,000	2250
114-S	R. Weiss #1	8-16-53	6141	5,000	2500
115-N	Pontzer #1	8-18-53	6116	13,700	3000
116-F	San Enz #1	8-18-53	6110	9,600	3700
117-S	Brookbank #2	8-20-53	5696	2,600	2300
118-S	Bartolette #2	8-20-53	6269	10,500	-
119-F	Overturf #1	8-21-53	-	9,000	-
120-S	A. J. Moser #1	8-21-53	5995	2,300	3100
121-S	Vause #1	8-22-53	6109	3,125	3925
122-F	Niccolo Pascuzzi #1	8-24-53	6160	1,800	3200
123-F	Thunderbird Camp #1	8-25-53	6137	5,700	2860
124-N	Johnson Ist. #3	8-25-53	6263	16,000	3200
125-N	Mackey #1	8-28-53	6105	14,500	-
126-I	Stiveson #1	8-31-53	6163	5,731	3000
127-I	W. A. Thurby #2	9-1-53	6276	5,300	2725
128-F	J. R. Roger #1	9-1-53	6272	5,700	2750
129-N	Gambel #1	9-3-53	6121	34,000	3360
130-I	Steffy #1	9-4-53	6215	7,000	3000
132-S	St. 2 Tr. 29	9-9-53	6947	4,332	3220
133-N	Johns #1	9-10-53	6073	8,530	3050
134-A	P.R.R. #2	9-10-53	5860	1,800	1000
135-S1	St. 1 Tr. 33	9-13-53	6392	7,350	3920
136-Q	Sagamore Hunt #4	9-22-53	6890	2,067	-
137-S	Overturf #2	9-25-53	6083	14,700	2500
138-N	H. Bleish #1	9-26-53	7011	7,300	-
139-S	Rothrock #2	9-28-53	6108	12,300	2590
140-S	B & O #2 (Mid-Atlantic)	9-28-53	6131	3,000	-
141-F	Coleman #1	9-29-53	6147	5,300	1960
142-N	Rothrock #3	9-30-53	6128	8,600	-

Table 1. 1950-1951

Year	Area	Population	Area	Population	Area	Population
1950	100	100	100	100	100	100
1951	100	100	100	100	100	100
1952	100	100	100	100	100	100
1953	100	100	100	100	100	100
1954	100	100	100	100	100	100
1955	100	100	100	100	100	100
1956	100	100	100	100	100	100
1957	100	100	100	100	100	100
1958	100	100	100	100	100	100
1959	100	100	100	100	100	100
1960	100	100	100	100	100	100
1961	100	100	100	100	100	100
1962	100	100	100	100	100	100
1963	100	100	100	100	100	100
1964	100	100	100	100	100	100
1965	100	100	100	100	100	100
1966	100	100	100	100	100	100
1967	100	100	100	100	100	100
1968	100	100	100	100	100	100
1969	100	100	100	100	100	100
1970	100	100	100	100	100	100
1971	100	100	100	100	100	100
1972	100	100	100	100	100	100
1973	100	100	100	100	100	100
1974	100	100	100	100	100	100
1975	100	100	100	100	100	100
1976	100	100	100	100	100	100
1977	100	100	100	100	100	100
1978	100	100	100	100	100	100
1979	100	100	100	100	100	100
1980	100	100	100	100	100	100
1981	100	100	100	100	100	100
1982	100	100	100	100	100	100
1983	100	100	100	100	100	100
1984	100	100	100	100	100	100
1985	100	100	100	100	100	100
1986	100	100	100	100	100	100
1987	100	100	100	100	100	100
1988	100	100	100	100	100	100
1989	100	100	100	100	100	100
1990	100	100	100	100	100	100
1991	100	100	100	100	100	100
1992	100	100	100	100	100	100
1993	100	100	100	100	100	100
1994	100	100	100	100	100	100
1995	100	100	100	100	100	100
1996	100	100	100	100	100	100
1997	100	100	100	100	100	100
1998	100	100	100	100	100	100
1999	100	100	100	100	100	100
2000	100	100	100	100	100	100
2001	100	100	100	100	100	100
2002	100	100	100	100	100	100
2003	100	100	100	100	100	100
2004	100	100	100	100	100	100
2005	100	100	100	100	100	100
2006	100	100	100	100	100	100
2007	100	100	100	100	100	100
2008	100	100	100	100	100	100
2009	100	100	100	100	100	100
2010	100	100	100	100	100	100
2011	100	100	100	100	100	100
2012	100	100	100	100	100	100
2013	100	100	100	100	100	100
2014	100	100	100	100	100	100
2015	100	100	100	100	100	100
2016	100	100	100	100	100	100
2017	100	100	100	100	100	100
2018	100	100	100	100	100	100
2019	100	100	100	100	100	100
2020	100	100	100	100	100	100

APPENDIX I (Continued)

Well No. and Area ^a	Name and Number	Drilling Completed	Depth	Flow Mcf/day	Initial W.H.P. psig
143-T	Charleroi Mt. Club #5	9-30-53	6305	8,000	2800
144-H	Johnson Mt. #2 (Keta)	10-1-53	6497	6,800	2600
145-F	Hot Shot Camp #1	10-3-53	6160	3,470	1980
146-H	Van Voorhies #1 (Kahle)	10-3-53	6114	11,000	2575
147-F	Mountain Camp #1	10-6-53	6190	3,750	1900
151-T	Ahlborn Coal Co. #1	10-12-53	6960	28,000	-
152-I	Thurby #4	10-13-53	6394	7,960	2800
154-G	Charleroi #10	10-14-53	6118	16,000	2550
155-E	Paasley Ober #1	10-17-53	6064	4,750	3600
156-AA	St. 2 Tr. 25	10-20-53	6999	6,000	3260
157-MM	St. 1 Tr. 32	10-21-53	7034	1,313	3140
158-L	St. 6 Tr. 20	10-21-53	-	3,400	3500
159-Z	St. 5 Tr. 29	10-24-53	6914	14,850	3290
160-L	Pearsall #1 (Sylvania)	10-26-53	6975	6,000	3375
161-E	Kothrock #1	10-26-53	6099	7,000	-
162-P	St. 2 Tr. 27	10-30-53	6935	10,849	3440
163-D	H. Hindrobariak #1	10-31-53	6092	1,438	-
164-I	St. 1 Tr. 34 A	11-2-53	6975	8,500	3625
165-FF	St. 9 Tr. 29	11-2-53	6900	14,671	3620
166-AA	St. 2 Tr. 30	11-2-53	6977	5,000	3460
167-G	Kothrock #5	11-2-53	6112	8,000	1850
168-F	Green #1	11-3-53	6154	3,300	1600
169-H	Charleroi R & G #7	11-4-53	6102	26,000	3250
171-F	Sam Ruz #1 (Shearer)	11-5-53	6310	5,900	-
172-E	Billings-Wason #2	11-10-53	6062	4,800	-
173-Q	St. 1 Tr. 27	11-11-53	6936	10,500	3210
175-Q	Sagamore Hunt Cl. #3	11-13-53	6128	22,500	3065
176-F	Corz Bennett #1	11-17-53	6185	1,474	1600
177-H	St. 1 Tr. 28	11-20-53	6938	20,100	3210
178-H	Kothrock #4	11-22-53	6119	11,250	-
179-R	St. 3 Tr. 29	11-25-53	6965	4,642	3210
180-H	B & R #4 (Mid-Atlantic)	11-25-53	6069	4,900	1500
181-AA	St. 1 Tr. 30	11-25-53	6566	412	3000
182-J	St. 1 Tr. 26	11-25-53	6903	4,073	3225
183-F	Belts #1	11-26-53	6157	4,200	1500
184-F	Howry #1	11-26-53	6842	7,000	-
185-F	Lawrence Winslow #1	11-28-53	6891	3,373	2600
186-H	Pontner #2	12-3-53	6175	8,200	1450
187-X	Denver Miller #1	12-3-53	6885	8,200	3750
188-I	Allegheny Camp #1	12-3-53	6169	3,600	1450
189-Q	Ahlborn Coal #1	12-3-53	6999	8,400	3150
190-F	Overturf #3	12-4-53	6240	1,100	-
191-R	Sagamore Hunt Cl. #2	12-4-53	-	6,500	3100
192-I	Thurby #5	12-4-53	6175	8,000	2100
193-H	Charleroi #9	12-5-53	6187	10,750	-
194-F	B & O #2 #5	12-5-53	6062	4,200	2400
195-F	Louis Jourdain #1	12-7-53	6199	1,350	1500
197-F	Arthur Davis #1	12-9-53	6212	2,700	1450

Year	Month	Day	Time	Location	Event
1900	Jan	1	10:00	St. Paul	St. Paul
1900	Jan	2	10:00	St. Paul	St. Paul
1900	Jan	3	10:00	St. Paul	St. Paul
1900	Jan	4	10:00	St. Paul	St. Paul
1900	Jan	5	10:00	St. Paul	St. Paul
1900	Jan	6	10:00	St. Paul	St. Paul
1900	Jan	7	10:00	St. Paul	St. Paul
1900	Jan	8	10:00	St. Paul	St. Paul
1900	Jan	9	10:00	St. Paul	St. Paul
1900	Jan	10	10:00	St. Paul	St. Paul
1900	Jan	11	10:00	St. Paul	St. Paul
1900	Jan	12	10:00	St. Paul	St. Paul
1900	Jan	13	10:00	St. Paul	St. Paul
1900	Jan	14	10:00	St. Paul	St. Paul
1900	Jan	15	10:00	St. Paul	St. Paul
1900	Jan	16	10:00	St. Paul	St. Paul
1900	Jan	17	10:00	St. Paul	St. Paul
1900	Jan	18	10:00	St. Paul	St. Paul
1900	Jan	19	10:00	St. Paul	St. Paul
1900	Jan	20	10:00	St. Paul	St. Paul
1900	Jan	21	10:00	St. Paul	St. Paul
1900	Jan	22	10:00	St. Paul	St. Paul
1900	Jan	23	10:00	St. Paul	St. Paul
1900	Jan	24	10:00	St. Paul	St. Paul
1900	Jan	25	10:00	St. Paul	St. Paul
1900	Jan	26	10:00	St. Paul	St. Paul
1900	Jan	27	10:00	St. Paul	St. Paul
1900	Jan	28	10:00	St. Paul	St. Paul
1900	Jan	29	10:00	St. Paul	St. Paul
1900	Jan	30	10:00	St. Paul	St. Paul
1900	Jan	31	10:00	St. Paul	St. Paul

APPENDIX I (Continued)

Well No. and Area ^a	Name and Number	Drilled Completed	Depth	Flow Gaf/day	Initial W.H.P. psig
198-T	St. 6 Tr. 29	12-10-53	6965	17,196	3100
199-P	Davis & Snyder #1	12-11-53	6136	2,560	1450
200-1	Ahlborn Coal #2	12-14-53	6390	2,300	2900
201-Q	St. 3 Tr. 27	12-23-53	7015	4,333	2350
202-AA	St. 3 Tr. 28	12-26-53	6964	1,100	3150
203-H	Dumble #2	12-27-53	6172	10,000	1250
205-F	Camp Kield #1	1-2-54	6137	2,646	1340
206-W	Wm. Laughlin #1	1-2-54	6258	3,125	3750
207-E	Sea Ene #2 (Mid-Atlantic)	1-2-54	6103	7,810	3100
208-E	Cooks Camp #1	1-4-54	6146	4,275	3600
209-AA	St. 8 Tr. 29	1-5-54	6940	342	1380
210-I	Stiverson #1	1-6-54	6380	7,500	2590
211-T	Charlton # & O #4	1-6-54	6380	7,500	2590
212-EE	St. 1 Tr. 31	1-8-54	7031	140	-
214-D	Schiller #1	1-13-54	6102	3,000	-
215-P	St. 1 Tr. 34	1-15-54	6383	2,388	1900
217-C	H. & J. Mason #2	1-15-54	6140	6,000	3750
218-F	King Gold Club #1	1-15-54	6116	2,000	1400
218-T	St. 7 Tr. 29	1-26-54	6893	9,311	-
219-P	Pearcull #2 (Sylvania)	1-26-54	6223	24,300	2723
220-T	Ahlborn Coal #2	1-26-54	6935	4,500	2150
221-F	Wm. Woodring #1 (Haddox)	1-27-54	6224	6,000	1600
222-F	Camp Liria #1	1-30-54	6183	1,650	1050
223-H	Charlton #3	2-1-54	6204	7,300	-
225-13	St. 5 Tr. 31	2-4-54	7007	4,875	3500
227-H	B & O #6	2-5-54	6118	6,100	-
228-B	B & O #2 (Gas. Sample)	2-10-54	6973	600	1800
229-E	Sea Ene #3	2-11-54	6224	1,438	3150
230-T	St. 12 Tr. 29	2-11-54	6940	3,523	2800
231-3	Ahlborn Coal #2	2-11-54	6905	7,000	2125
232-AA	St. 1 Tr. 29	2-12-54	6905	4,760	2510
233-H	Hurby #6	2-13-54	6923	4,100	1450
234-I	Dollinger #1	2-13-54	6442	1,178	3580
236-W	Hoffelinger #1	2-15-54	6254	557	-
239-O	Wm. Shuck #1	2-19-54	6052	1,433	3000
240-W	Shingledecker #1	2-20-54	6259	1,300	3750
241-00	St. 1 Tr. 36	3-1-54	7155	12,800	3830
243-W	St. 6 Tr. 31	3-4-54	6444	40,234	3560
245-O	Dante Run Coal #1	3-10-54	6092	400	2340
246-P	St. 5 Tr. 27	3-12-54	6159	82	1650
247-F	B & O #1 (J.I. Shearer)	3-13-54	6132	557	950
248-G	Ahlborn Coal #3	3-16-54	6993	5,538	1850
249-R	St. 4 Tr. 28	3-16-54	6998	4,770	2050
252-EE	St. 1 Tr. 34	3-22-54	7295	125	-
254-W	St. 1 Tr. 38	3-25-54	6226	5,454	3850
255-L	St. 2 Tr. 25	3-30-54	6995	4,860	2600
256-P	St. 4 Tr. 27	3-30-54	7122	13,000	1850
257-CC	St. 5 Tr. 28	3-39-54	6911	6,000	1850

TABLE 1. (continued)

Year	Age	Sex	Location	Notes	Ref. (Year)
1988	17.5	♂	Chesapeake	1st yr 0-1	1988
1989	18.0	♂	Chesapeake	1st yr 0-1	1989
1990	18.5	♂	Chesapeake	1st yr 0-1	1990
1991	19.0	♂	Chesapeake	1st yr 0-1	1991
1992	19.5	♂	Chesapeake	1st yr 0-1	1992
1993	20.0	♂	Chesapeake	1st yr 0-1	1993
1994	20.5	♂	Chesapeake	1st yr 0-1	1994
1995	21.0	♂	Chesapeake	1st yr 0-1	1995
1996	21.5	♂	Chesapeake	1st yr 0-1	1996
1997	22.0	♂	Chesapeake	1st yr 0-1	1997
1998	22.5	♂	Chesapeake	1st yr 0-1	1998
1999	23.0	♂	Chesapeake	1st yr 0-1	1999
2000	23.5	♂	Chesapeake	1st yr 0-1	2000
2001	24.0	♂	Chesapeake	1st yr 0-1	2001
2002	24.5	♂	Chesapeake	1st yr 0-1	2002
2003	25.0	♂	Chesapeake	1st yr 0-1	2003
2004	25.5	♂	Chesapeake	1st yr 0-1	2004
2005	26.0	♂	Chesapeake	1st yr 0-1	2005
2006	26.5	♂	Chesapeake	1st yr 0-1	2006
2007	27.0	♂	Chesapeake	1st yr 0-1	2007
2008	27.5	♂	Chesapeake	1st yr 0-1	2008
2009	28.0	♂	Chesapeake	1st yr 0-1	2009
2010	28.5	♂	Chesapeake	1st yr 0-1	2010
2011	29.0	♂	Chesapeake	1st yr 0-1	2011
2012	29.5	♂	Chesapeake	1st yr 0-1	2012
2013	30.0	♂	Chesapeake	1st yr 0-1	2013
2014	30.5	♂	Chesapeake	1st yr 0-1	2014
2015	31.0	♂	Chesapeake	1st yr 0-1	2015
2016	31.5	♂	Chesapeake	1st yr 0-1	2016
2017	32.0	♂	Chesapeake	1st yr 0-1	2017
2018	32.5	♂	Chesapeake	1st yr 0-1	2018
2019	33.0	♂	Chesapeake	1st yr 0-1	2019
2020	33.5	♂	Chesapeake	1st yr 0-1	2020
2021	34.0	♂	Chesapeake	1st yr 0-1	2021
2022	34.5	♂	Chesapeake	1st yr 0-1	2022
2023	35.0	♂	Chesapeake	1st yr 0-1	2023
2024	35.5	♂	Chesapeake	1st yr 0-1	2024
2025	36.0	♂	Chesapeake	1st yr 0-1	2025
2026	36.5	♂	Chesapeake	1st yr 0-1	2026
2027	37.0	♂	Chesapeake	1st yr 0-1	2027
2028	37.5	♂	Chesapeake	1st yr 0-1	2028
2029	38.0	♂	Chesapeake	1st yr 0-1	2029
2030	38.5	♂	Chesapeake	1st yr 0-1	2030

APPENDIX I (Continued)

<u>Well No. and Area</u>	<u>Name and Number</u>	<u>Drilling Completed</u>	<u>Depth</u>	<u>Flow Wcf/day</u>	<u>Initial W.H.P. psig</u>
258-M	St. 4 Tr. 33	4-3-54	6201	4,254	3500
259-I	Thurty #7	4-3-54	6918	21,000	1450
260-Y	St. 5 Tr. 34A	4-10-54	6394	8,500	2825
261-U	Bleish #3	4-12-54	6941	968	1550
262-T	Ahlborn Coal #4	4-12-54	6863	4,000	-
263-W	Lay Laughlin #1	4-13-54	6254	852	2700
268-X	St. 3 Tr. 31	4-16-54	6381	7,810	3260
269-R	St. 8 Tr. 26	4-18-54	6741	2,427	2000
270-Q	Sagsmore #5	4-18-54	6475	6,400	1775
272-YI	St. 2 Tr. 38	4-22-54	6625	6,000	3625
274-T	Ahlborn Coal #5	4-27-54	6938	4,000	1575
275-T	St. 1 Tr. 34B	4-28-54	7151	1,000	3550
276-B	St. 2 Tr. 34A	4-28-54	7060	308	1950
277-OO	St. 3 Tr. 32	4-29-54	7176	5,523	2980
280-W	Bleish #4	5-1-54	7001	8,500	1425
281-X	Parks #1 (Yohle et al)	5-3-54	6428	3,250	2875
282-E	Billings and Maxon #1	5-3-54	6119	4,600	2160
284-V	Bateman #1	5-5-54	6146	696	700
285-Q	St. 7 Tr. 25	5-7-54	6060	2,350	2150
286-X	Jamolson #1	5-8-54	6254	475	3000
287-W	St. 1 Tr. 25	5-12-54	6992	7,035	2450
288-OB	St. 2 Tr. 33	5-17-54	7019	4,151	3160
289-W	Logue #1	5-17-54	6247	1,400	2500
290-U	St. 13 Tr. 29	5-19-54	6892	4,900	2800
291-WB	St. 5 Tr. 30	5-20-54	7024	5,731	2560
292-X	Parks #1 (Layton)	5-20-54	6393	2,438	2500
294-J	St. 6 Tr. 26	5-21-54	6929	3,081	2450
295-T	Charleroi #12	5-27-54	7039	4,400	1850
296-X	St. 10 Tr. 29	5-27-54	6944	850	2500
297-Y	St. 4 Tr. 34A	5-29-54	7112	250	1650
298-OD	St. 6 Tr. 6	6-1-54	7080	3,479	2940
299-WH	St. 5 Tr. 33	6-1-54	6313	14,210	2916
301-J	St. 2 Tr. 26	6-5-54	6934	2,085	2175
302-Z	St. 3 Tr. 34A	6-7-54	7029	4,272	2650
304-K	St. 9 Tr. 26	6-9-54	6969	4,973	2050
305-OO	St. 1 Tr. 34C	6-10-54	7106	1,217	2625
306-U	St. 14 Tr. 29	6-10-54	6809	38,000	3125
307-WH	St. 2 Tr. 32	6-10-54	7111	1,174	1790
308-KK	St. 3 Tr. 33	6-11-54	6220	38,000	3125
309-F	Holben #1	6-12-54	6147	600	-
310-OD	St. 2 Tr. 34C	6-19-54	7102	12,572	3300
311-K	R. L. Peersall #4	6-21-54	6331	2,200	1320
312-WH	St. 2 Tr. 37	6-21-54	6224	4,450	2980
313-I	Thurty #3	6-22-54	6939	1,500	-
315-X	Parks #1 (Bailey)	6-26-54	6366	1,800	2060
316-Q	Sagsmore #7	6-28-54	6491	2,800	1425
319-D	St. 11 Tr. 26	7-2-54	6208	189	2100
320-I	Thurty #8	7-7-54	7046	700	1300

Year	Month	Day	Time	Location	Event	Remarks
1900	Jan	1	10:00	St. Paul	St. Paul	St. Paul
1900	Jan	2	10:00	St. Paul	St. Paul	St. Paul
1900	Jan	3	10:00	St. Paul	St. Paul	St. Paul
1900	Jan	4	10:00	St. Paul	St. Paul	St. Paul
1900	Jan	5	10:00	St. Paul	St. Paul	St. Paul
1900	Jan	6	10:00	St. Paul	St. Paul	St. Paul
1900	Jan	7	10:00	St. Paul	St. Paul	St. Paul
1900	Jan	8	10:00	St. Paul	St. Paul	St. Paul
1900	Jan	9	10:00	St. Paul	St. Paul	St. Paul
1900	Jan	10	10:00	St. Paul	St. Paul	St. Paul
1900	Jan	11	10:00	St. Paul	St. Paul	St. Paul
1900	Jan	12	10:00	St. Paul	St. Paul	St. Paul
1900	Jan	13	10:00	St. Paul	St. Paul	St. Paul
1900	Jan	14	10:00	St. Paul	St. Paul	St. Paul
1900	Jan	15	10:00	St. Paul	St. Paul	St. Paul
1900	Jan	16	10:00	St. Paul	St. Paul	St. Paul
1900	Jan	17	10:00	St. Paul	St. Paul	St. Paul
1900	Jan	18	10:00	St. Paul	St. Paul	St. Paul
1900	Jan	19	10:00	St. Paul	St. Paul	St. Paul
1900	Jan	20	10:00	St. Paul	St. Paul	St. Paul
1900	Jan	21	10:00	St. Paul	St. Paul	St. Paul
1900	Jan	22	10:00	St. Paul	St. Paul	St. Paul
1900	Jan	23	10:00	St. Paul	St. Paul	St. Paul
1900	Jan	24	10:00	St. Paul	St. Paul	St. Paul
1900	Jan	25	10:00	St. Paul	St. Paul	St. Paul
1900	Jan	26	10:00	St. Paul	St. Paul	St. Paul
1900	Jan	27	10:00	St. Paul	St. Paul	St. Paul
1900	Jan	28	10:00	St. Paul	St. Paul	St. Paul
1900	Jan	29	10:00	St. Paul	St. Paul	St. Paul
1900	Jan	30	10:00	St. Paul	St. Paul	St. Paul
1900	Jan	31	10:00	St. Paul	St. Paul	St. Paul

APPENDIX I (Continued)

Well No. and Area	Name and Number	Drilled Completed	Depth	Flow McF/day	Initial W.B.P. psig
322-I	St. 12 Tr. 26	7-13-54	6918	2,218	2050
323-LL	St. 6 Tr. 33	7-16-54	6366	1,857	1620
324-KK	St. 4 Tr. 38	7-20-54	6287	213	2275
325-X	St. 16 Tr. 29	7-24-54	6373	920	2450
326-F	Pascuzzi #1	7-24-54	6063	2,463	1300
327-00	St. 4 Tr. 36	7-29-54	7095	990	1850
328-BB	St. 4 Tr. 30	7-29-54	6920	2,936	-
329-T	St. 17 Tr. 29	7-30-54	7004	42,000	1910
332-E	St. 10 Tr. 26	8-2-54	6866	1,279	2350
334-FF	St. 11 Tr. 31	8-13-54	7102	1,000	2500
335-X	Herman Morre #1	8-14-54	6232	4,500	3700
337-KK	St. 1 Tr. 29	8-24-54	6473	6,100	3050
339-V	Denver Miller #3	9-3-54	6750	2,800	3150
340-X	Rosensteel #1	9-4-54	6232	3,300	3100
341-LL	St. 8 Tr. 33	9-14-54	6303	5,741	1340
342-HH	St. 3 Tr. 33	9-15-54	7007	996	1990
343-R	Sagamore #6	9-16-54	6417	2,542	1280
344-W	St. 7 Tr. 31	9-18-54	6315	1,081	1580
346-V	Dollinger #1	10-8-54	6262	5,080	2650
349-LL	St. 9 Tr. 33	10-11-54	6420	239	1410
350-B	St. 7 Tr. 20	10-11-54	6907	1,271	1450
351-Y	St. 11 Tr. 29	10-12-54	6950	3,373	1650
353-B	Billings and Mason #3	10-21-54	6830	2,250	1530
354-V	Steve Rupprecht #1	10-27-54	6902	4,200	2290
356-L	Pearcell #5	10-29-54	7021	1,885	1425
357-W	Paul Chase #1	11-8-54	6341	10,833	3600
358-V	Dollinger #2	11-9-54	6760	3,769	2310
359-W	Crafutt (Ross Hrs.) #1	11-13-54	6204	2,166	3175
362-C	H. & J. Mason #1	11-29-54	6932	134	-
363-KK	St. 2 Tr. 29	11-31-54	7145	1,246	-
364-JJ	St. 2 Tr. 34	12-3-54	7113	680	1400
365-X	Claude Chase #1 (Kahle)	12-10-54	6239	3,921	1907
366-V	Walter Tuxle #1	12-13-54	6216	4,047	1700
368-W	St. 3 Tr. 37	12-20-54	6884	3,425	3500
370-X	Boosters Club #1	1-17-55	6182	5,500	2500
371-X	Crown Control #1	1-17-55	6220	1,600	2160
372-W	St. 4 Tr. 37	1-19-55	7029	5,731	2725
373-JJ	St. 11 Tr. 33	2-22-55	6283	4,275	-
374-II	St. 5 Tr. 38	2-23-55	6943	2,900	1800
375-II	St. 5 Tr. 37	2-25-55	7076	894	2850
376-W	Hall Chase #2	2-26-55	6598	3,000	2400
377-Z	St. 13 Tr. 29	3-3-55	7029	4,775	1120
378-BB	St. 7 Tr. 30	3-10-55	7225	696	1140
379-Y	St. 20 Tr. 29	3-16-55	6508	4,055	1125

Year	Month	Day	Time	Location	Event
1997	Jan	1	10:00	St. John's	Christmas Eve
1997	Jan	2	10:00	St. John's	Christmas Eve
1997	Jan	3	10:00	St. John's	Christmas Eve
1997	Jan	4	10:00	St. John's	Christmas Eve
1997	Jan	5	10:00	St. John's	Christmas Eve
1997	Jan	6	10:00	St. John's	Christmas Eve
1997	Jan	7	10:00	St. John's	Christmas Eve
1997	Jan	8	10:00	St. John's	Christmas Eve
1997	Jan	9	10:00	St. John's	Christmas Eve
1997	Jan	10	10:00	St. John's	Christmas Eve
1997	Jan	11	10:00	St. John's	Christmas Eve
1997	Jan	12	10:00	St. John's	Christmas Eve
1997	Jan	13	10:00	St. John's	Christmas Eve
1997	Jan	14	10:00	St. John's	Christmas Eve
1997	Jan	15	10:00	St. John's	Christmas Eve
1997	Jan	16	10:00	St. John's	Christmas Eve
1997	Jan	17	10:00	St. John's	Christmas Eve
1997	Jan	18	10:00	St. John's	Christmas Eve
1997	Jan	19	10:00	St. John's	Christmas Eve
1997	Jan	20	10:00	St. John's	Christmas Eve
1997	Jan	21	10:00	St. John's	Christmas Eve
1997	Jan	22	10:00	St. John's	Christmas Eve
1997	Jan	23	10:00	St. John's	Christmas Eve
1997	Jan	24	10:00	St. John's	Christmas Eve
1997	Jan	25	10:00	St. John's	Christmas Eve
1997	Jan	26	10:00	St. John's	Christmas Eve
1997	Jan	27	10:00	St. John's	Christmas Eve
1997	Jan	28	10:00	St. John's	Christmas Eve
1997	Jan	29	10:00	St. John's	Christmas Eve
1997	Jan	30	10:00	St. John's	Christmas Eve
1997	Jan	31	10:00	St. John's	Christmas Eve

APPENDIX II - CALCULATIONS*

A. Determination of Reserves

1. P/Z Values for Graphical Solution (Figure 4)

Gas Analysis: methane 97.0%; ethane 2.10%; propane 0.1%; oxygen 0.1%; nitrogen 0.5; carbon dioxide 0.2%; molecular weight 16.3; critical pressure 673 psia; critical temperature 348°R.

Reservoir temperature 150°F^{**}; surface temperature 60°F.

Original reservoir pressure $P = 4035$ psia as measured at the surface plus the pressure caused by the weight of the gas column in the well P_x . P_x was calculated as follows:

$$P_w = \frac{144 ZRT P_x}{M} - .5 P_x$$

where $P_w = 4035$ psia well head pressure

$Z = .9$ (from compressibility chart for natural gas, using a pseudo reduced pressure P_r of $4035 \div 673 = 6.0$, and a pseudo reduced temperature T_r of $565^\circ R \div 348 = 1.622$)

$R = 10.71$ (gas constant)

$T = 565^\circ R$ (average temperature in the well)

$H = 6500$ feet (average depth)

$M = 16.3$ (molecular weight)

thus

$$4035 = \frac{(144)(.9)(10.71)(565) P_x}{(16.3)(6500)} - .5 P_x$$

$P_x = 583$ pounds per square inch.

*All calculations by slide rule

**Estimate based on 140°F. as measured for Leidy gas field

2. We follow the procedure outlined in Figure 2.

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3. third of these is the fact that the
4. fourth of these is the fact that the
5. fifth of these is the fact that the

$$E^{\circ} = \frac{RT}{nF} \ln K = \frac{0.0591}{2} \log K = 0.0295 \log K$$

[illegible]

12345678910111213141516171819202122232425262728293031323334353637383940414243444546474849505152535455565758596061626364656667686970717273747576777879808182838485868788899091929394959697989910010110210310410510610710810911011111211311411511611711811912012112212312412512612712812913013113213313413513613713813914014114214314414514614714814915015115215315415515615715815916016116216316416516616716816917017117217317417517617717817918018118218318418518618718818919019119219319419519619719819920020120220320420520620720820921021121221321421521621721821922022122222322422522622722822923023123223323423523623723823924024124224324424524624724824925025125225325425525625725825926026126226326426526626726826927027127227327427527627727827928028128228328428528628728828929029129229329429529629729829930030130230330430530630730830931031131231331431531631731831932032132232332432532632732832933033133233333433533633733833934034134234334434534634734834935035135235335435535635735835936036136236336436536636736836937037137237337437537637737837938038138238338438538638738838939039139239339439539639739839940040140240340440540640740840941041141241341441541641741841942042142242342442542642742842943043143243343443543643743843944044144244344444544644744844945045145245345445545645745845946046146246346446546646746846947047147247347447547647747847948048148248348448548648748848949049149249349449549649749849950050150250350450550650750850951051151251351451551651751851952052152252352452552652752852953053153253353453553653753853954054154254354454554654754854955055155255355455555655755855956056156256356456556656756856957057157257357457557657757857958058158258358458558658758858959059159259359459559659759859960060160260360460560660760860961061161261361461561661761861962062162262362462562662762862963063163263363463563663763863964064164264364464564664764864965065165265365465565665765865966066166266366466566666766866967067167267367467567667767867968068168268368468568668768868969069169269369469569669769869970070170270370470570670770870971071171271371471571671771871972072172272372472572672772872973073173273373473573673773873974074174274374474574674774874975075175275375475575675775875976076176276376476576676776876977077177277377477577677777877978078178278378478578678778878979079179279379479579679779879980080180280380480580680780880981081181281381481581681781881982082182282382482582682782882983083183283383483583683783883984084184284384484584684784884985085185285385485585685785885986086186286386486586686786886987087187287387487587687787887988088188288388488588688788888989089189289389489589689789889990090190290390490590690790890991091191291391491591691791891992092192292392492592692792892993093193293393493593693793893994094194294394494594694794894995095195295395495595695795895996096196296396496596696796896997097197297397497597697797897998098198298398498598698798898999099199299399499599699799899910001001100210031004100510061007100810091010101110121013101410151016101710181019102010211022102310241025102610271028102910301031103210331034103510361037103810391040104110421043104410451046104710481049105010511052105310541055105610571058105910601061106210631064106510661067106810691070107110721073107410751076107710781079108010811082108310841085108610871088108910901091109210931094109510961097109810991100110111021103110411051106110711081109111011111112111311141115111611171118111911201121112211231124112511261127112811291130113111321133113411351136113711381139114011411142114311441145114611471148114911501151115211531154115511561157115811591160116111621163116411651166116711681169117011711172117311741175117611771178117911801181118211831184118511861187118811891190119111921193119411951196119711981199120012011202120312041205120612071208120912101211121212131214121512161217121812191220122112221223122412251226122712281229123012311232123312341235123612371238123912401241124212431244124512461247124812491250125112521253125412551256125712581259126012611262126312641265126612671268126912701271127212731274127512761277127812791280128112821283128412851286128712881289129012911292129312941295129612971298129913001

$$g^{\mu\nu} Z_{\mu\nu} = \frac{g^{\mu\nu} \langle \partial_{\mu} \partial_{\nu} (2\pi i \omega_0) (F_{\mu\nu}) \rangle}{\langle F_{\mu\nu} F_{\mu\nu} \rangle} \rightarrow \frac{2\pi i \omega_0}{\langle F_{\mu\nu} F_{\mu\nu} \rangle}$$

^aEffective date of 1997 is assumed for 1996.

Therefore, the original reservoir pressure $P = 4035 + 583 = 4618$ pounds per square inch absolute. The corresponding compressibility factor $Z = .97$, using $T_r = 610^\circ R$ (reservoir temperature) $\div 348 = 1.75$, and $P_r = 4618 \div 673 = 6.85$. The original $P/Z = 4618 \div .97 = 4755$.

On May 31, 1954, P_x and Z were calculated as shown above.

(See Figures 7 and 8)

$$\text{May 31, 1954 } P/Z = \frac{P}{Z} \div \frac{P_x}{Z} = \frac{2505 \div 390}{.882} = 3280$$

2. Analytical Method

Original gas = gas produced \div gas remaining

Considering the reservoir storage space and the reservoir temperature as remaining constant, and using the gas produced as of May 31, 1954 (Appendix III):

$$\frac{381 P_1 V}{Z_1 RT} = 89,315,450,000 \div \frac{381 P_2 V}{Z_2 RT}$$

where 381 = standard cubic feet per mole

$P_1 = 4618$ psia (original reservoir pressure)

$P_2 = 2895$ psia (May 31, 1954 reservoir pressure)

$V =$ reservoir storage space in cubic feet

$Z_1 = .97$ (compressibility factor at original reservoir pressure)

$Z_2 = .882$ (compressibility factor at May 31, 1954 reservoir pressure)

$R = 10.71$ (gas constant)

$T = 610^\circ R$ (reservoir temperature)

$$V = \frac{89,315,450,000 RT}{381(P_1/Z_1 - P_2/Z_2)}$$

$$V = \frac{(89,315,450,000)(10.71)(610)}{381(4755 - 3280)} = 1.04 \times 10^9 \text{ cubic feet}$$

$$\text{Original gas} = \frac{381 P_1 V}{Z_1 RT} = \frac{(381)(4618)(1.04 \times 10^9)}{(.97)(10.71)(610)}$$

$$= 289 \text{ billion standard cubic feet}$$

Therefore, the vertical reaction pressure is $\frac{1}{2} \times 100 = 50$ pounds per square inch absolute. The corresponding compressive force is

$$F_c = 50 \times 100 = 5000 \text{ (vertical pressure)} \quad \frac{1}{2} \times 100 = 50 \text{ and } F_c = 5000$$

$$\text{and } F_c = 5000 \text{ and } F_c = 5000 \text{ and } F_c = 5000$$

the net force $F_c = 5000$ and $F_c = 5000$ and $F_c = 5000$

(see Figure 1 and 2)

$$\text{the net force } F_c = 5000 \text{ and } F_c = 5000 \text{ and } F_c = 5000$$

2. Vertical force

Outboard air is not present & not reacting

Consequently the vertical reaction force and the reaction

pressure are identical, and with the net

pressure of 50, 100, 150, 200, 250, 300, 350, 400, 450, 500, 550, 600, 650, 700, 750, 800, 850, 900, 950, 1000

$$\frac{F_c}{F_c} = \frac{5000}{5000} = 1 \text{ and } \frac{F_c}{F_c} = \frac{5000}{5000} = 1$$

For a vertical force of 5000

$F_c = 5000$ (vertical reaction pressure)

$F_c = 5000$ (vertical reaction pressure)

$F_c = 5000$ (vertical reaction pressure)

$F_c = 5000$ (vertical reaction pressure)

$F_c = 5000$ (vertical reaction pressure)

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$F_c = 5000$ (vertical reaction pressure)

$F_c = 5000$ (vertical reaction pressure)

$F_c = 5000$ (vertical reaction pressure)

$F_c = 5000$ (vertical reaction pressure)

2. Vertical reaction force

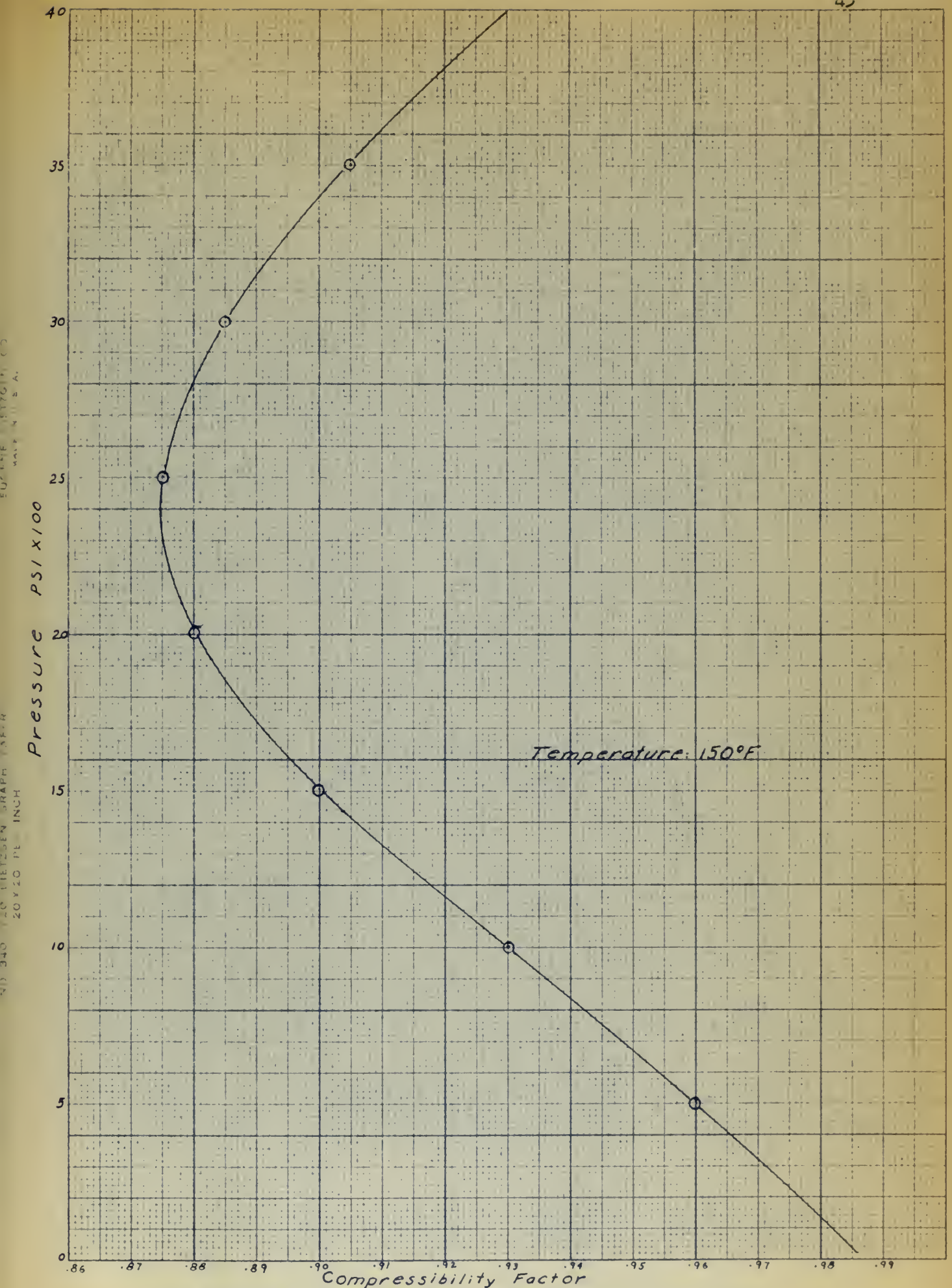


Figure 7. Compressibility Factor vs. Pressure

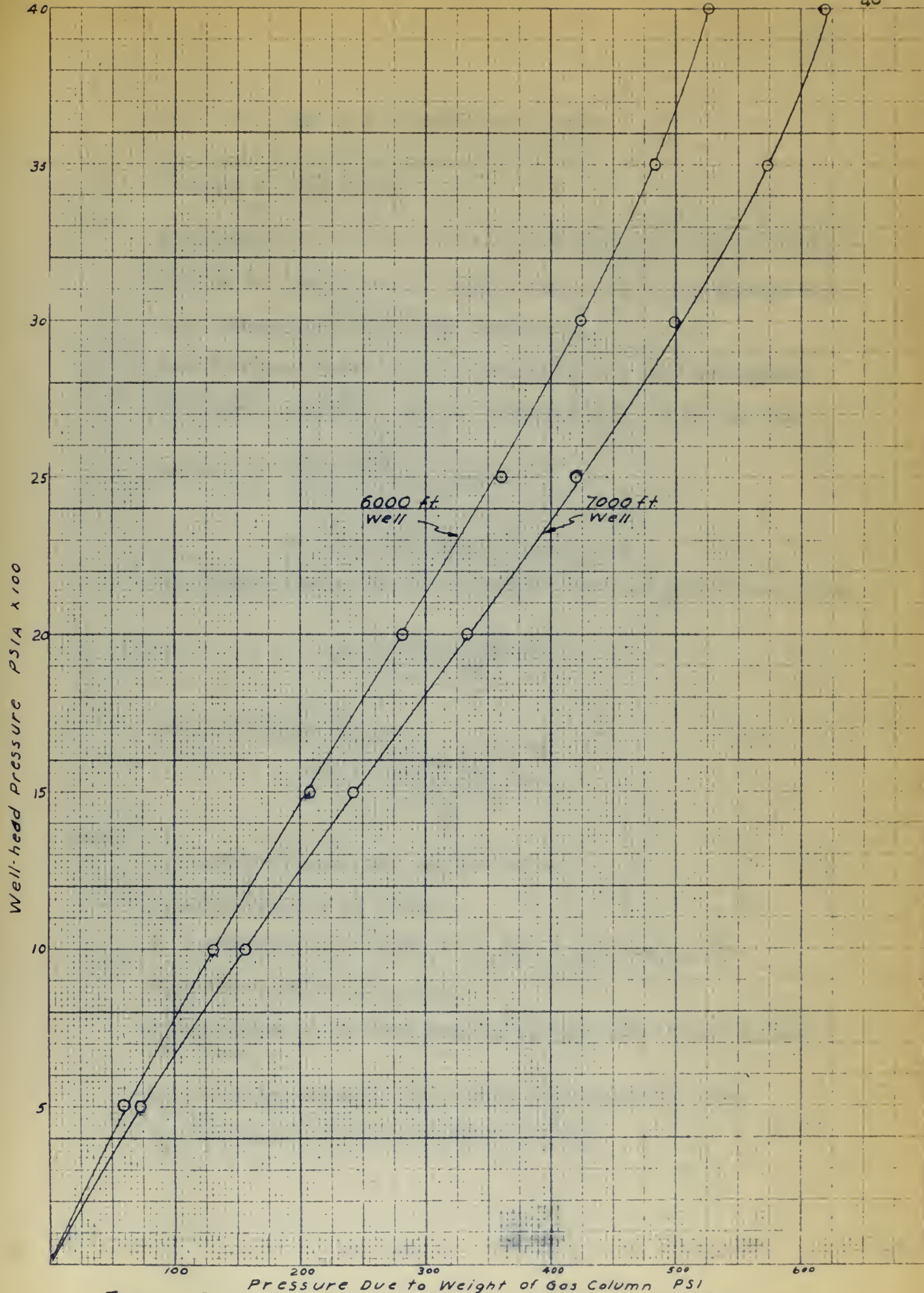


Figure 0. Pressure Due to Weight of Gas Column vs Well-head Pressure

B. Determination of Porosity

$$\text{Porosity} = \frac{\text{pore volume}}{\text{bulk volume}}$$

Pore volume = 1.04×10^9 cu. ft. (as shown in Appendix II, Section A, 2 on the preceding page) plus an estimated 20 per cent of the pore volume for connate water saturation.

Bulk volume = approximately 42,000 acres x 17 feet average sand thickness x 43,560 cu. ft. per acre-foot = 31.1×10^9 cu. ft.

$$\text{Porosity} = \frac{(1.04 \times 10^9)(100)}{(31.1 \times 10^9)(1-.20)} = 4.18\%$$

C. Determination of Permeability

The Darcy's Law radial flow equation²³ for viscous isothermal flow

$$Q_D = \frac{19.88 Kh (P_e^2 - P_w^2)}{P_b \mu \ln \frac{r_e}{r_w}}$$

can be rewritten to give

$$Q_s = \frac{703 Kh (P_f^2 - P_s^2)}{\mu \ln \frac{r_e}{r_w} T_f}$$

where

Q_s = standard cubic feet per 24 hours

K = permeability in darcies

h = effective sand thickness in feet (approximately 17)

P_f = reservoir pressure, psia

P_s = pressure at the sand face (or flowing bottom hole pressure) psia

r_e = drainage radius of the well in feet (estimated 1000)

r_w = radius of the well bore in feet (.256)

2. Estimated at 10000

$$\text{Density} = \frac{\text{mass}}{\text{volume}}$$

For volume 1.0×10^3 or 1000 (as shown in Appendix II, Section

4, 2 on the preceding page) and an estimated 20 per cent of the

new volume for certain water reduction

This volume is approximately 1000 cubic ft. of water

Volume is 1000 cu. ft. for water-foot 1.1×10^3 or 1100

$$\text{Density} = \frac{(1.0 \times 10^3)(1.00)}{(11.1 \times 10^3)(1.00)} = 0.09$$

3. Estimated at 1000000

The density of water is 1.00 g/cm³ for water at 4°C.

$$\frac{(1.0 \times 10^3)(1.00)}{1.0 \times 10^3} = 1.00$$

can be written as 1.00

$$\frac{(1.0 \times 10^3)(1.00)}{1.0 \times 10^3} = 1.00$$

where

V_0 is volume of water at 4°C.

V_1 is volume of water at 100°C.

V_2 is volume of water at 100°C (approximately 1000)

V_3 is volume of water at 100°C

V_4 is volume of water at 100°C (the volume of water at 100°C is 1000)

V_5 is volume of water at 100°C (estimated 1000)

V_6 is volume of water at 100°C (1000)

μ = viscosity in centipoises (about .021)

T_f = flowing temperature, $^{\circ}\text{R}$ (610)

In the equation $Q = C(P_f^2 - P_s^2)^n$, when n equals one, C is equivalent to:

$$\frac{703 Kh}{\mu \ln r_o/r_w T_f}$$

Therefore,

$$K = \frac{C \mu \ln r_o/r_w T_f}{703 h}$$

substituting:

$$K = \frac{(.456)(.021)(8.27)(610)}{(703)(17)}$$

$$K = .00405 \text{ darcy or } 4.05 \text{ millidarcies}$$

(1994, 2002) and others all rely heavily on a

(iii) π^{th} approximation is better than π^{th}

[illegible]

1982 4-63

1954

$$\frac{2.7 \times 10^3 \text{ kg} \times 4.2}{1.01} \approx 1.1 \times 10^4 \text{ kg}$$

$$\frac{(0.0177)(3)(750)(100)(1)}{11.11(1)} = 4.7$$

2000-2001: 20.4 to 20.0, a 2

APPENDIX III

Monthly and Cumulative Production
(Thousands of Standard Cubic Feet)

<u>Date</u>	<u>Monthly</u>	<u>Cumulative</u>
<u>July, 1952</u>	188,059	188,059
August	335,508	523,567
September	487,600	1,011,167
October	626,391	1,637,558
November	646,559	2,284,117
December	779,402	3,063,519
<u>January, 1953</u>	707,450	3,770,969
February	675,666	4,446,635
March	702,671	5,149,306
April	699,867	5,849,173
May	914,232	6,763,405
June	2,064,370	8,827,775
July	3,325,838	12,153,613
August	3,813,343	15,966,956
September	4,631,769	20,598,725
October	5,921,232	26,519,957
November	8,547,966	35,067,923
December	9,417,934	44,485,857
<u>January, 1954</u>	9,566,001	54,051,858
February	8,455,139	62,523,997
March	8,814,765	71,338,762
April	9,079,005	80,417,767
May	8,897,687	89,315,454
June	8,632,640	97,948,094
July	9,035,862	106,983,956
August	8,402,474	115,386,430
September	7,224,472	122,610,902
October	6,493,945	129,104,847
November	6,122,523	135,227,370
December	5,605,069	140,832,439
<u>January, 1955</u>	5,392,746	146,225,185
February	4,238,335	150,463,520
March	4,306,508	154,770,028
April	3,835,448	158,605,476
May	3,591,968	162,197,444

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Year	Amount	Year	Amount
1900	100.00	1901	100.00
1902	100.00	1902	100.00
1903	100.00	1903	100.00
1904	100.00	1904	100.00
1905	100.00	1905	100.00
1906	100.00	1906	100.00
1907	100.00	1907	100.00
1908	100.00	1908	100.00
1909	100.00	1909	100.00
1910	100.00	1910	100.00
1911	100.00	1911	100.00
1912	100.00	1912	100.00
1913	100.00	1913	100.00
1914	100.00	1914	100.00
1915	100.00	1915	100.00
1916	100.00	1916	100.00
1917	100.00	1917	100.00
1918	100.00	1918	100.00
1919	100.00	1919	100.00
1920	100.00	1920	100.00
1921	100.00	1921	100.00
1922	100.00	1922	100.00
1923	100.00	1923	100.00
1924	100.00	1924	100.00
1925	100.00	1925	100.00
1926	100.00	1926	100.00
1927	100.00	1927	100.00
1928	100.00	1928	100.00
1929	100.00	1929	100.00
1930	100.00	1930	100.00
1931	100.00	1931	100.00
1932	100.00	1932	100.00
1933	100.00	1933	100.00
1934	100.00	1934	100.00
1935	100.00	1935	100.00
1936	100.00	1936	100.00
1937	100.00	1937	100.00
1938	100.00	1938	100.00
1939	100.00	1939	100.00
1940	100.00	1940	100.00
1941	100.00	1941	100.00
1942	100.00	1942	100.00
1943	100.00	1943	100.00
1944	100.00	1944	100.00
1945	100.00	1945	100.00
1946	100.00	1946	100.00
1947	100.00	1947	100.00
1948	100.00	1948	100.00
1949	100.00	1949	100.00
1950	100.00	1950	100.00
1951	100.00	1951	100.00
1952	100.00	1952	100.00
1953	100.00	1953	100.00
1954	100.00	1954	100.00
1955	100.00	1955	100.00
1956	100.00	1956	100.00
1957	100.00	1957	100.00
1958	100.00	1958	100.00
1959	100.00	1959	100.00
1960	100.00	1960	100.00
1961	100.00	1961	100.00
1962	100.00	1962	100.00
1963	100.00	1963	100.00
1964	100.00	1964	100.00
1965	100.00	1965	100.00
1966	100.00	1966	100.00
1967	100.00	1967	100.00
1968	100.00	1968	100.00
1969	100.00	1969	100.00
1970	100.00	1970	100.00
1971	100.00	1971	100.00
1972	100.00	1972	100.00
1973	100.00	1973	100.00
1974	100.00	1974	100.00
1975	100.00	1975	100.00
1976	100.00	1976	100.00
1977	100.00	1977	100.00
1978	100.00	1978	100.00
1979	100.00	1979	100.00
1980	100.00	1980	100.00

APPENDIX IV

Producing Wells and Dry Holes by Dates

<u>Date</u>	<u>Total No. Prod. Wells</u>	<u>Total No. Dry Holes</u>	<u>Date</u>	<u>Total No. Prod. Wells</u>	<u>Total No. Dry Holes</u>
Sept., <u>1951</u>	1	-	July, <u>1953</u>	53	52
October	1	-	August	75	52
November	1	-	September	91	53
December	1	1	October	107	57
January, <u>1952</u>	1	1	November	127	59
February	1	4	December	144	61
March	1	7	January, <u>1954</u>	161	62
April	1	9	February	175	67
May	2	15	March	187	72
June	3	22	April	201	80
July	5	28	May	217	82
August	7	31	June	233	86
September	8	33	July	243	88
October	12	37	August	247	93
November	14	39	September	253	94
December	19	40	October	260	98
January, <u>1953</u>	24	40	November	265	100
February	28	40	December	269	101
March	30	44	January, <u>1955</u>	272	102
April	33	45	February	276	102
May	37	47	March	277	102
June	46	51	April	277	102
			May	277	102

continued on page 10

Year	Month	Day	Time	Location	Event
1901	Jan	1	10:00	St. Paul	St. Paul
1901	Jan	2	10:00	St. Paul	St. Paul
1901	Jan	3	10:00	St. Paul	St. Paul
1901	Jan	4	10:00	St. Paul	St. Paul
1901	Jan	5	10:00	St. Paul	St. Paul
1901	Jan	6	10:00	St. Paul	St. Paul
1901	Jan	7	10:00	St. Paul	St. Paul
1901	Jan	8	10:00	St. Paul	St. Paul
1901	Jan	9	10:00	St. Paul	St. Paul
1901	Jan	10	10:00	St. Paul	St. Paul
1901	Jan	11	10:00	St. Paul	St. Paul
1901	Jan	12	10:00	St. Paul	St. Paul
1901	Jan	13	10:00	St. Paul	St. Paul
1901	Jan	14	10:00	St. Paul	St. Paul
1901	Jan	15	10:00	St. Paul	St. Paul
1901	Jan	16	10:00	St. Paul	St. Paul
1901	Jan	17	10:00	St. Paul	St. Paul
1901	Jan	18	10:00	St. Paul	St. Paul
1901	Jan	19	10:00	St. Paul	St. Paul
1901	Jan	20	10:00	St. Paul	St. Paul
1901	Jan	21	10:00	St. Paul	St. Paul
1901	Jan	22	10:00	St. Paul	St. Paul
1901	Jan	23	10:00	St. Paul	St. Paul
1901	Jan	24	10:00	St. Paul	St. Paul
1901	Jan	25	10:00	St. Paul	St. Paul
1901	Jan	26	10:00	St. Paul	St. Paul
1901	Jan	27	10:00	St. Paul	St. Paul
1901	Jan	28	10:00	St. Paul	St. Paul
1901	Jan	29	10:00	St. Paul	St. Paul
1901	Jan	30	10:00	St. Paul	St. Paul
1901	Jan	31	10:00	St. Paul	St. Paul

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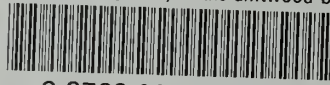
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